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16. ABSTRACT

Health effects literature primarily related to inhalation exposure to methanol was collected, evaluated, tabulated, and summarized. Approximately 160 documents were collected from computerized and manual literature searches covering the period 1901-1980. Pharmacologists and an M.D. epidemiologist rated the documents according to their applicability to the study and their methodology. The approximately 25 documents considered useful for deriving a range of concern for human exposure to methanol from automotive emissions were tabulated. The pages of tables detail the results of acute, repeated dose, and chronic testing of mice, rats, rabbits, dogs, monkeys and humans as well as human occupational studies. A brief summary of oral and skin absorption toxicity is included. Most of the documents evaluated are described in an annotated bibliography.

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METHANOL HEALTH EFFECTS
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FINAL TASK 7 REPORT
December 31, 1981

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PREFACE

This report on health effects of methanol was prepared by Midwest Research Institute (MRI) on Task No. 7 under Contract No. 68-03-2928, "Health Effects Support for the Emission Control Technology Division" for the U.S. Environmental Protection Agency.

Health effects literature primarily related to inhalation exposures to methanol has been collected, evaluated, tabulated, and summarized so that this report can be used to derive a range of concern for human exposure to vehicular atmospheric emissions of methanol. Because of the possible use of methanol as a fuel, a brief summary of the health effects from ingestion and skin absorption has been included.

Task activities were coordinated by the project leader, Mrs. Bonnie L. Carson, Senior Chemist, and task leader, Ms. Joy L. McCann, Assistant Scientist. Documents were rated and summarized by senior pharmacologists, Drs. Harry V. Ellis III, and Betty L. Herndon, of MRI, and epidemiologist, Larry H. Baker, M.D., MRI consultant, who is Associate Professor of Community Health at the University of Kansas Medical Center. Data were tabulated and the annotated bibliography prepared by Ms. McCann and Mrs. Carson. This study was performed under the general supervision of Dr. Edward W. Lawless, Head, Chemical Impact Assessment Section.

Mr. Robert J. Garbe was the project officer for the Emission Control Technology Division, U.S. Environmental Protection Agency, and Ms. Colleen DeMeyer served as Branch Technical Representative.

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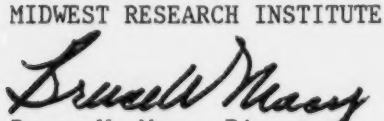

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SUMMARY

GOALS AND METHODS

The purpose of this compilation of data on methanol (MeOH)* inhalation exposures is to assist the Emissions Control Technology Division (ECTD) of the U.S. Environmental Protection Agency (EPA) to establish the ranges of exposure conditions that are of concern for MeOH in exhausts from vehicles equipped with catalytic converters and to be able to advise automobile manufacturers thereof. The situations of concern are during malfunctions and during exposures in traffic jams, parking and home garages, and other situations where little dilution of the exhaust is expected before inhalation. Most of the report is, as directed by ECTD, in the form of tables based on the literature reviewed. Data from exposures at levels higher than those of primary concern are included because strictly relevant information was scarce and these related data might prove helpful in assessing health effects at lower levels.

In addition to MeOH inhalation data, literature related to oral ingestion and skin absorption was also retrieved and reviewed for this task. Brief summaries of the toxicity and range of concern associated with these two routes of exposure are included. These were included because of the recognition by ECTD that MeOH is being proposed as an alternative fuel in automobiles, and such usage would result in skin absorption from spills during handling and possible ingestion from siphoning or other careless handling.

Documents relevant to this study of health effects from exposure to MeOH were identified from manual and computerized literature searches and then rated in a two-step process by the project pharmacologists and epidemiologist. First, the document received an A, B, C, or D rating according to its applicability for deriving a range of concern for MeOH inhalation exposure. Second, if the paper was not a low-rated, foreign language document,** a theoretical paper, a review, or a nontoxicology experimental paper, it received a numerical score based on itemized features that should be present in an ideal report. For the most part, only A- and B-rated documents were tabulated; but when data were limited as with MeOH, C- and D-studies were also tabulated when it was felt they contributed some useful information to the overall evaluation of health hazards. Blanks in the tables should be construed as denoting missing information in the documents.

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* Chemical formula CH_3OH. Also called methyl alcohol and wood alcohol.

** Most foreign language articles rated C and D were usually not translated. Each foreign language document tentatively rated A or B from an English language abstract or brief examination of the paper was translated in sufficient degree to judge the experimental design and details. These papers were numerically scored from the translation.

BACKGROUND INFORMATION ON METHANOL TOXICITY

Methanol is a well-known poison, discussed today in most standard reference works on toxic chemicals (such as Gosselin et al., 1976). In the past, MeOH's toxicity was debated, and, as late as 1936, doubts existed as to the toxicity of pure MeOH. The toxicity of wood alcohol was attributed to its impurities by some early authorities (Bennett et al., 1953). A 1904 report by Wood and Buller documented the earliest cases of MeOH poisoning; it stated that 275 cases of blindness or death attributable to wood alcohol were reported between 1856 (when the first scientific report of toxicity was made) and 1904. Nevertheless, MeOH was a frequent component of liniments, toilet articles, perfumes, and some patent medicines well into this century (Wood, 1912).

Practically all the MeOH toxicity data involve its ingestion with, or as a substitute for, ethanol (ethyl alcohol). The immediate symptom is an inebriation, indistinguishable from that from ethanol ingestion. After 12 to 18 h, the characteristic MeOH toxicity appears, presumably caused by its metabolites, formaldehyde and formic acid. Symptoms include headache, weakness, leg cramps, and vertigo; nausea and vomiting sometimes with violent abdominal pain; back and leg pain; vision defects; rapid, shallow breathing from metabolic acidosis; and weak, rapid pulse with hypotension; progressing to apathy and coma, or to excitement, mania, and convulsions. Death, if it occurs, is usually from respiratory failure. In nonfatal cases, convalescence is often protracted and complicated by debility, blindness, and kidney problems.

Relatively few experimental studies on MeOH toxicity have been published, and most of them involved very large doses, mechanistic studies of the retinal toxicity, or both. Most human reports are case studies, with little exposure data. Toxicity has occurred from ingestion, inhalation, contact, and confounded exposure through two or all three routes (Wood and Buller, 1904; McLean et al., 1980).

Methanol's toxicity (especially its ocular effects) is generally believed to be caused by its metabolites, although its metabolism is not fully understood. In humans and other primates, MeOH is first oxidized to formaldehyde by the enzyme catalase, but in lower animals this oxidation is effected by alcohol dehydrogenase. The highly reactive formaldehyde quickly disappears from the tissue but was formerly believed to be the cause of toxic effects. More recently, the further metabolites, formic acid or formate esters, have been proposed to be the toxic products. Tephly et al. (1974; 1979) have reviewed the available information on the metabolism of MeOH.

BIOASSAY STUDIES

The bioassay data were limited in applicability to human toxicity, but did demonstrate that in the animal <u>in vitro</u> systems studied, MeOH is not very toxic and not mutagenic. In the one respiratory tissue study, 0.4 to

1.4 mg MeOH in aerosol at the rate of 27 mL/s inhibited ciliary activity in the esophageal tract of the leopard frog. Another study found low concentrations of MeOH, ≦ 0.02 mMol increased release of lung prostaglandins; higher MeOH levels decreased rate of release.

INHALATION STUDIES

Chao (1959) exposed rats 12 h/day for 8 weeks. He found definite toxicity (respiratory tract irritation, liver degeneration, cortical neuropathy) at 50 mg/m^3, but not at 1.77 mg/m^3. Ubaydullayev (1968) found minor toxicity in rats exposed continuously for 90 d to 5.31 mg/m^3, but none at 0.57 mg/m^3. Sayers et al. (1942) exposed dogs (including pups bred and born during the exposure) to about 600 mg/m^3 for 8 h/d, 7 d/wk for over a year. Although blood MeOH levels were typically 7 to 15 mg/dL after a daily exposure, no adverse effects were noted.

Human case reports (e.g., Wood and Buller, 1904; Tyson, 1912) have shown toxicity from MeOH in lacquer thinner and similar products. Although some skin contact would have occurred, this exposure is presumably primarily from inhalation.

Several human experimental studies have determined an odor threshold for MeOH. The highest reported value was 7,800 mg/m^3 (May, 1966). Leonardos et al. (1969) reported identification of MeOH odor at 133 mg/m^3, while Hellman and Small (1974) reported the same results at 70 mg/m^3. Minimum detectable thresholds include 4.3 to 11 mg/m^3 (Chao, 1959); 4.5 mg/m^3 (Ubaydullayev, 1968); and 5.7 mg/m^3 (Hellman and Small, 1974). The discrepancy may be due to the purity of the MeOH used in testing.

Two groups studied the effects of MeOH on nervous system reflexes. Chao (1959) found that 3.3 to 3.7 mg/m^3 was the threshold for degradation of light sensitivity (dark adaptation), with 1.8 to 2.4 mg/m^3 having no effect. Ubaydullayev (1968) found EEG changes, of dubious significance at 1.17 mg/m^3, but not 1.01 mg/m^3, in subjects selected for olfactory sensitivity.

The reports of studies involving occupational exposure to MeOH are not very useful for our purposes. Several studies were confounded by the presence of other chemicals, were poorly controlled, or the reports lack necessary information. Kingsley and Hirsch (1954-1955) found that office workers complaining of recurrent headaches were exposed to ~ 22 to 500 mg $MeOH/m^3$ from spirit duplicating machines and those workers actually operating the machines had more severe symptoms. One study (Barmann and Angerer, 1979) found a significant increase of formic acid (a MeOH metabolite) in the blood and urine of print shop workers exposed to 113 to 178 mg $MeOH/m^3$. Another study (Dutkiewicz and Blockowicz, 1967) found that workers exposed to 45 to 1,640 mg $MeOH/m^3$ had levels of MeOH in their urine (during the work shift and immediately afterwards) ranging from 0.09 to 36.4 mg/L, the level varying according to level of exposure.

INGESTION STUDIES

These usually involved overwhelming doses, since most animal studies were prompted by fatal or near-fatal human accidents. The classic case report is the Atlanta epidemic of 1951 (Bennett et al., 1953), involving 323 patients and 41 deaths from 90 gal. of contaminated moonshine whiskey. Very notable is the extreme variability in individual sensitivity. One patient died from ingesting 6 mL of MeOH, while another survived 200 mL. Cooper and Kini (1962) cite contrasting reports in which one man consumed 540 mL without irreversible toxicity, while blindness occurred with ingestion of 15 mL and death from ingestion of 30 mL in another case.

SKIN ABSORPTION

All inhalation exposures (except mask tests) involve the possibility of skin absorption. McCord (1931) showed that skin absorption and inhalation exposures produced similar effects in animals. Yant and Schrenk (1937) observed similar results in dogs given MeOH by inhalation, stomach tube, or subcutaneously. Dutkiewicz et al. (1980) reported similar results in humans given MeOH orally or on the skin. They calculated a dermal absorption rate of 0.192 $mg/cm^2/min$, but did not report toxicity from doses of 1.7 mL.

ENVIRONMENTAL CONTRIBUTIONS TO HUMAN EXPOSURE

Cigarette smoking is a source of MeOH exposure for humans. One gas phase analysis of cigarette smoke found 180 μg MeOH/cigarette (Grob, 1965); another study found 13 and 10 μg MeOH/40 mL puff of smoke from unfiltered and filtered cigarettes, respectively (Newsome et al. 1965). Newsome and Keith were reported to have found a range of 100 to 200 μg MeOH/cigarette (Maddox and Mamenta, 1977).

Alcoholic beverages may contribute to an individual's exposure and accumulation of MeOH in the blood. Levels of 3.9 to 105.5 mg MeOH/L have been reported in commercial alcoholic beverages (Schneck, 1979; Majchrowicz and Mendelson, 1971; Carroll, 1970). Alcoholics with high blood ethanol levels (> 100 mg/100 mL) tend to accumulate MeOH in their blood at levels up to 2.7 mg/100 mL after an 11-d intoxication (Majchrowicz and Mendelson, 1971). Some of the MeOH accumulated by alcoholics is believed to be derived from endogenous sources and accumulated due to ethanol's disruption of MeOH oxidation and elimination. That some MeOH is endogenously produced is supported by studies finding MeOH levels of 0.06 to 0.49 μg/L and 0.3 to 3.4 ppm in normal human breath (Eriksen and Kulharni, 1963; Jansson and Larson, 1969). Another study of 54 healthy nonsmoking adults found only 3.6% of 387 breath samples to contain MeOH; the mean concentration when found was 0.549 mg/m^3 (Krotoszynski et al., 1979).

Certain foods have been reported to contain MeOH. Brussels sprouts, celery, onions, parsnips, potatoes, and swede (rutabaga) were vegetables that contained "large" or "very large" levels (unquantified) of MeOH after boiling for 30 min. Frozen peas and corn and instant coffee contained little or no MeOH after cooking (Self et al., 1963). Eriksen and Kulharni (1963) found that levels of MeOH in human breath tended to increase 1 to 2 h after eating.

A potential contribution to human exposure would be the exhaust of vehicles fueled by MeOH or MeOH/gasoline mixtures. Review of the numerous literature data on MeOH levels in vehicular exhaust was beyond the scope of this task.

INTERNATIONAL RECOMMENDATIONS AND STANDARDS

Several U.S. agencies and professional associations have regulations and recommendations concerning the level of MeOH in different situations. The Occupational Safety and Health Administration standard for MeOH exposure in the workplace is 200 mg/m^3 for a ceiling level. The American Conference of Governmental Industrial Hygienists suggests 260 mg $MeOH/m^3$ as the time-weighted-average threshold limit value (TLV) and 310 mg/m^3 as the short-term-exposure limit (ACGIH, 1978). The American National Standard Institute (ANSI) listed a ceiling concentration of 600 ppm (~ 798 mg/m^3) MeOH with the provision that the 8-h time-weighted average concentration of MeOH is at or below 200 ppm (~ 260 mg/m^3) (AIHA, 1978).

In the U.S.S.R., the Maximum Allowable Concentrations (MAC) in air for 1972 were 5 mg $MeOH/m^3$ in the workplace, and 1 mg/m^3 as the one-time limit and 0.5 mg/m^3 as the average limit in populated places (U.S.S.R., 1972). The Czechoslovakian normal workplace MAC for 1970 was 100 mg/m^3 with 500 mg/m^3 as the short-term, single exposure permitted level (ILO, 1970).

RECOMMENDED RANGE OF CONCERN

MeOH is rapidly absorbed by all exposure routes, and is notorious for the wide range of human susceptibility to it. The range of response for oral ingestion varies from recovery after doses of 200 to 500 mL to death and blindness after doses of only 6 to 60 mL. That a dose of 6 mL (approximately 1 teaspoon) could cause death appears surprisingly low, the report is from Bennett et al. (1953), a relatively recent case study involving hospital observation and treatment of poison victims. Dutkiewicz et al. (1980) reported no toxicity from ingestion of 1.67 g (~ 2 mL). These data suggest a range of concern of 0.1 to 1 mL for ingestion of MeOH while handling it as an automotive fuel.

For inhalation, the TLV is currently set at 260 mg/m^3, but at that level, a workperson inhaling 10 m^3 of air over an 8-h period would have an intake of 26 g/d or 32.5 mL/d. This is well above the upper limit of the ingestion range of concern. Chao (1959) recommended a TLV limit of 1.5 mg/m^3 after a study finding eye sensitivity unaffected by 1.8 to 2.4 mg/m^3. The data of Ubaydullayev (1968) tend to support this level; eye sensitivity was unaffected at 3.1 mg/m^3. Changes in cerebral cortex activity were detected at 1.17 and 1.47 mg/m^3 but not at 1.0 mg/m^3. In an isolated case, Humperdinck (1941) reported one worker had vision problems from exposure to 1.6 to 10.9 mg/m^3. For inhalation of MeOH, a range of concern of 1.0 to 3.0 mg/m^3 is suggested. (An 8-h exposure would result in intake of 10 to 31 mg/d or 0.013 to 0.039 mL/d.)

MeOH is readily absorbed through the skin, and cases have been reported of death, blindness, and other injury from MeOH either spilled on clothes or applied to the skin. A rate for skin absorption of MeOH by humans of 0.192 mg/cm^2/min has been reported (Dutkiewicz et al., 1980). Immersing a whole hand (~ 440 cm^2) in MeOH for 2 min would result in the absorption of 170 mg (0.2 mL) of MeOH or within the range of concern for ingestion. Long or repeated skin contact with a solution of 1% or above of MeOH would give exposures in the range of concern and should be avoided. Appropriate personnel protective equipment, such as rubber gloves, to prevent skin contact is suggested for handling MeOH fuel.

SECTION I

INTRODUCTION

This report on methanol (MeOH)* was compiled as the seventh task under Contract No. 68-03-2928, "Health Effects Support for the Emission Control Technology Division (U.S. Environmental Protection Agency, Ann Arbor, Michigan)." The goal of the project is to evaluate health effects literature on specific compounds emitted from automobiles equipped with emission-control devices (specifically catalytic converters), not for the purpose of creating a criteria document but to identify a range of concern or a no-observable-effect level for each compound to serve as guidance to automobile manufacturers in their development of future emission-control devices. This particular report also contains a brief review of the health effects of exposure to MeOH by ingestion and skin absorption as might occur in handling MeOH if it is adopted as an alternative automobile fuel.

The present report was meant to be largely a series of charts or tables of pertinent data with the tests logically ordered according to exposure levels. The narrative summary was not meant to describe again each paper in detail. There are admittedly some disadvantages in not doing so; e.g., some of the graduations in effect that the authors of a particular paper observed may be diluted or lost when the details are spread throughout an exceptionally large table, or between several tables. Papers described in a largely narrative fashion, however, often are difficult to compare. Results that appear within their source paper to be quite definitive may appear less so or even anomalous when juxtaposed in tabular format with other results from similar studies. Hence, the present format was designed to facilitate comparisons.

Literature related to health effects of MeOH exposure was collected mainly by computer search of TOXLINE and TOXBACK and manual search through the NIOSH criteria document on MeOH. Approximately 160 papers and other documents were evaluated, but only about 25 contained original data suitable for tabulation.

Experimental animal and human exposure studies were evaluated and summarized by a senior Ph.D. pharmacologist. Occupational exposures were rated by an epidemiologist with an M.D. degree. Figure I-1 is the form used for rating documents by the project pharmacologist and epidemiologist. Each

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* Also called methyl alcohol and wood alcohol. The chemical formula is CH_3OH.

Article No. 4997-7-_ _ _ _

CHECK WHERE APPROPRIATE:	PAPER DEFECTIVE 0	PAPER IS SUB-STANDARD 1	STANDARD QUALITY 2	SUPERIOR PAPER 3
1. Do they state/limit the problem?				
2. Adequacy of sample				
3. Replicability				
4. Controls/control procedures				
5. Completeness and comprehensibility of results				
6. Validity of conclusions, interpretation of data				

7. Applicability to health effects of MeOH as guidance for establishing a range of concern in automobile emissions.
(circle one)

a. Clearly, directly applies/assists in establishing a range of concern
(Chronic human studies; acute exposure of humans if minimal effects.)

b. Research requires major inferences; potentially applicable.
(Chronic animal studies; acute human, maximal effect; acute animal, minimal effects.)

c. Useful hints or suggestions; tentatively applicable.
(Acute animal, lethal effects; studies in above categories but effects reported not appropriate.)

d. Not directly applicable (peripheral useful information).

Figure I-1. Form for report rating.

document was rated in a two-step procedure according to the applicability of its subject matter and to the quality of the experimental methodology. The letter assigned in rating the document A, B, C, or D was derived from the corresponding lower case letters under item 7 in Figure I-1. Thus, a study was rated A if it directly applies to or assists in establishing a level of concern for exposure to MeOH. The second part of the rating is the methodology score. The document reviewer checked off which score should be given for each of the first six items in Figure I-1, and the total was written at the top of the pages along with the letter that rated the paper's applicability. In some cases, such as reviews, theoretical papers, and low-rated foreign language documents, a paper may have received an applicability rating (generally C or D), but none on methodology.

Data, including the MRI-assigned rating, from the papers were tabulated by mid-level scientists. Information for each topic heading was carefully sought; so if blanks appear in the table, the reader can generally assume the data were not given. Sometimes a group published several papers that described the same tests. To avoid redundancy, all pertinent papers were cited and the test was described as well as possible from all the papers' descriptions.

The final written summary of the tabulated data was also performed by a senior pharmacologist. This summary attempts to reflect objectively the scientific community's thought as a whole and does not reflect the tabular material by weight. The tables reflect the amount of data generated, and the summary puts the evaluated data in perspective with the overall scientific community's opinions.

The references are cited in an annotated bibliography that includes not only each document's rating, but also a brief comment on its pertinence (or lack of same) to the study. English titles are given for foreign language documents. An abbreviation of the language is given in parentheses at the end of the citation.

The report is organized into the following chapters: II - Bioassay Tests; III - Experimental Animal Inhalation Exposures; IV - Experimental Human Inhalation Exposures; and V - Occupational Exposures and Human Case Reports. The Summary precedes the entire report.

SECTION II

BIOASSAYS

Bioassay studies involving MeOH are limited. A brief summary of the literature is presented here rather than a tabulation of the limited data. These in vitro studies contribute little in our understanding of the mechanisms of activity or toxicity of the chemical in man that would be useful to the task of determining a range of concern for human exposure to MeOH in automobile exhaust.

Mazur et al. (1969) noted the gut contraction that occurred in rabbits exposed to MeOH, defined the fraction or metabolite responsible, and measured its effects on the contraction amplitude and coronary output of the isolated rabbit heart. Methanol (and formic acid), 0.0001 M, decreased both rate and cardiac output while formaldehyde at that concentration had no effect.

Thomas et al. (1980) measured prostaglandin (PgE_2) released from rat isolated perfused lungs exposed to varying concentrations of aliphatic alcohols. MeOH in increasing concentrations, up to 0.02 mM, caused increased PgE_2 release; higher concentrations caused a decrease.

In the one bioassay study involving respiratory tissue, Tremer et al. (1959) found that 0.4-1.4 mg MeOH in aerosols at the rate of 27 mL/s for 2 s inhibited mucus flow of ciliated epithelium from the esophageal tract of the leopard frog.

Gotterer (1969) showed that rat liver beta-hydroxybutyrate dehydrogenase enzyme assay required 4,600 mM MeOH to produce 50% inhibition. For comparison, quinine produced 50% inhibition with 0.11 mMol.

Hohne and Patsch (1969) studied bacterial inhibition by several alcohols. Two percent MeOH had no effect on Staphylococcus aureus, Escherischia coli, and Klebsiella pneumoniae were unaffected by 1% MeOH. It was less toxic to these organisms than was isopropyl or isomeric butyl alcohols.

Khan (1969) showed that the microsomes of the common housefly produced an epoxide with the cyclodiene aldrin, and that MeOH at high concentrations stimulated this microsomal epoxidation.

Obe and Ristow (1977) found no sister chomatid exchange (SCE) following 7- to 8-d treatment of Chinese hamster ovary cells in culture with 0.1% (by volume) MeOH daily.

SECTION III

EXPERIMENTAL ANIMAL INHALATION EXPOSURES

This chapter presents the essential parameters of the studies involving animal inhalation experiments. Relatively few studies were found in the literature and a number of these involve rather high-level exposures (from 55,214 to 5,320 mg/m^3); effects reported range from a 6-h LD_{50} for mice of 54,530 mg/m^3 to no illnesses when dogs inhaled MeOH at 13,300 mg/m^3 for 3 min, 8 times/d for 160 d. Changes were reported in the nervous systems of rats and rabbits, with repeated and chronic doses of 5 to 5.3 mg/m^3. No effects reported at 1.7 mg/m^3 for 12 h/d for 90 d or to 0.57 mg/m^3 continuously for 90 d.

The primary organization of data is by species, in order of increasing weight (mice to monkeys in this case). Within a species, studies are divided by dosing duration: acute exposure ($\leq$ 24 h), repeated exposure, and chronic exposure ($\geq$ 90 d). Within a single table, reported results are listed in order of decreasing exposure level.

In the animal exposure tables in this section (Tables III-1 through III-10), the column headed "Total length of experiment" includes not only the total length of exposure to MeOH but also any recovery time observed in the study. This recovery time was included to note the endurance or reversibility of the toxic effects.

TABLE III-1. MICE--ACUTE EXPERIMENTAL EXPOSURE TO MeOH

Compound(s) and concentration(s) in mg/m^3 (ppm)	Humidity/ temp.	Mode of exposure	Species/ strain/ age/weight	No. of test animals	No. of controls	Duration and frequency of exposure	Total length of experiment	Effects	Reference and rating
MeOH ~ 55,214 (41,514)		2.1-L inhalation chamber with only head exposed	Mice, Swiss-Webster	8 M	Served as own controls	10 min	10 min	RD_{50} value calculated from mice responses; RD_{50} is defined as the concentration of chemical that produces a 50% decrease in respiration rate.	Kane et al. (1980) C-11
MeOH ~ 54,530 (41,000)	22-25°C	28-L inhalation chamber	Mice			6 h, once	30 h (all deaths 24 h after exposure counted)	Calculated 6-h LC_{50}. Livers of exposed animals had a significant degree of centrilobular fatty metamorphosis. Eyes had acute keroconjunctivitis characterized by an infiltrate of neutrophils into the cornea and conjunctiva.	Scott (1978) B-9

TABLE III-2. MICE--REPEATED DOSE EXPERIMENTAL EXPOSURE TO MeOH

Compound(s) and concentration(s) in mg/m^3 (ppm)	Humidity/ temp.	Mode of exposure	Species/ strain/ age/weight	No. of test animals	No. of controls	Duration and frequency of exposure	Total length of experiment	Effects	Reference and rating
MeOH 1,329 ± 29 (999 ± 22)	22-25°C	28-L inhalation chamber	Mice	66 M	30 M	6 h/d, 5 d/wk, 3 wk	~ 6 wk	No abnormal behavior and no deaths. Weight remained steady. Livers appeared normal but were significantly lower in weight from animals sacrificed during exposure. Liver triglyceride levels decreased significantly during exposure but returned to control levels during 18-d recovery period. No retinal degeneration or other histological damage to eyes of mice examined at end of exposure.	Scott (1978) B-9

TABLE III-3. RATS--ACUTE EXPERIMENTAL EXPOSURE TO MeOH

Compound(s) and concentration(s) in mg/m^3 (ppm)	Humidity/ temp.	Mode of exposure	Species/ strain/ age/weight	No. of test animals	No. of controls	Duration and frequency of exposure	Total length of experiment	Effects	Reference and rating
MeOH 6,650 (5,000)		250-L inhalation chamber	Rats, Sprague-Dawley 200-450 g	≥ 6	≥ 6	1 h	9 h	No change in carboxyhemoglobin levels at 2 or 4 h postexposure.	Ciuchta et al. (1979) C-8

TABLE III-4. RATS--REPEATED DOSE EXPERIMENTAL EXPOSURE TO MeOH

Compound(s) and concentration(s) in mg/m^3 (ppm)	Humidity/ temp.	Mode of exposure	Species/ strain/ age/weight	No. of test animals	No. of controls	Duration and frequency of exposure	Total length of experiment	Effects	Reference and rating
MeOH 50			Albino rats	10	10	12 h/d except for days off for 3 mo	≥ 18 wk (1 mo habituation to test conditions plus 3-wk recovery period)	A slight change of the ratio of the chronaxy of the muscle antagonists was seen in the 2nd wk which became more expressed in the 4th wk. Starting from the 8th wk of poisoning, the values of the chronaxies of the flexors and extensors converged, but by the end of poisoning they had diverged. The ratio returned to normal in the recovery period. The histopathological examination revealed catarrhal-desquamative tracheitis, bronchitis, hyperplasia of the tracheal submucous glands, whose infiltrates were of a slightly lymphoid character. Changes in the trachea were somewhat more expressed than in the bronchi and lung tissue. Swelling, hypertrophy of the muscle layer of some medium- and low-caliber arteries of the lungs, and very weakly expressed degernative changes in the liver (nonuniform staining of the nuclei and granularity of the protoplasm) were sometimes observed. Dendrites of the neurons of the brain cortex were distinctly deformed and their branches had disappeared. The top dendrites of the pyrimidal cells were more affected.	Chao Chen-Tsi (1959) A-8 (human) B-8 (animal)
MeOH 1.77			Albino rats	10	10	12 h/d except for days off for 3 mo)	≥ 18 wk (1 mo habituation to test conditions plus 3 wk recovery period)	The concentration was lower than the human odor threshold (2.4 mg/m^3) or the threshold of reflex action on light sensitivity of the eye. At the end of poisoning, all rats were healthy and active and had gained weight. No classical toxic symptoms (irritation or nervous system affection). The average chronaxy of the muscle extensors was significantly higher than the average chronaxy of the flexors, as it was in the control group.	Chao Chen-Tsi (1959) A-8 (human) B-8 (animal)

(continued)

TABLE III-4. (continued)

Compound(s) and concentration(s) in mg/m^3 (ppm)	Humidity/ temp.	Mode of exposure	Species/ strain/ age/weight	No. of test animals	No. of controls	Duration and frequency of exposure	Total length of experiment	Effects	Reference and rating
								No changes were observed in the internal organs; but during staining, neurons of the brain cortex of one rat showed distinct deformations of the dendrites. The author proposed 1.5 mg/m^3 as a suitable value for the MAC.	

TABLE III-5. RATS--CHRONIC EXPERIMENTAL EXPOSURE TO MeOH

Compound(s) and concentration(s) in mg/m³ (ppm)	Humidity/ temp.	Mode of exposure	Species/ strain/ age/weight	No. of test animals	No. of controls	Duration and frequency of exposure	Total length of experiment	Effects	Reference and rating
MeOH 5.31 ± 0.62			Rats, white, 100-200 g	15 M	15 M	Continuous, 90 d	90 d plus recovery period (20 d ?)	Animals were active, weight normal, and appeared healthy. Significant changes in both motor and antagonist chronaxy ratios beginning 6th wk, returned to normal during recovery period. Drop in excretion of coproporphyrin in urine beginning 7th wk, normalization on d 20 of recovery. Decrease in cholinesterase activity beginning 6th wk, normalization during recovery period. Change in protein fractions in blood beginning 7th wk.	Ubaydullayev (1968) B-8
HHCO, 0.5-0.6 MeOH, 5.0-6.0 Following intratracheal introduction of resin-treated or untreated coal dust		Not given	Rats	Nos. not given. Rats dosed with untreated coal dust and not exposed to HCHO and MeOH.	Continuous?	6 mo	6 mo	This collagen content per identical lung weight was significantly higher in the exposed group that had been dosed with untreated coal dust. (14.8 ± 0.6 versus 8.7 ± 0.4 mg %; $P \leq 0.07$.) More severe disturbances in lung structure both in the bronchial tree and the respiratory branch occurred in exposed rats predosed with treated dust. The changes in the bronchi were also more severe in the exposed rats than in the controls.	Gadzhiev et al. (1977) D-4
MeOH 0.57 ± 0.059			Rats, white, 100-200 g	15 M	15 M	Continuous, 90 d	90 d plus recovery period (20 d ?)	Animals were active, weight normal, and appeared healthy. No effect on chronaxy index, or on blood and urine parameters measured.	Ubaydullayev (1968) B-8

TABLE III-6. RABBITS--CHRONIC EXPERIMENTAL EXPOSURE TO MeOH

Compound(s) and concentration(s) in mg/m^3 (ppm)	Humidity/ temp.	Mode of exposure	Species/ strain/ age/weight	No. of test animals	No. of controls	Duration and frequency of exposure	Total length of experiment	Effects	Reference and rating
MeOH ~ 5 ("near the 1968 MAC")			Rabbits, mature	6	6	4 h/d, 6-7 mo	6-7 mo; animals killed by air embolism and eyes immediately enucleated	General nervous system changes were observed for other animals exposed to hexanol, heptanol, nonanol, and decanol as well as methanol. The reactions of the retina were of the same type after exposure to all the alcohols at the levels of their MACs. The structure and functional capacity of the retina, optic nerve, optic chiasm, optic tract, anterior corpora quadrigemina, and cerebral optic lobe were damaged. The retinal changes resembled those reported from oral dosing at MeOH--pathological changes at the ganglionic cells and proliferation of the glial elements. Irritation of the nerve fibers of the optic nerve, optic chiasm, and optic tract was expressed in "corkscrew" twisting of the fine nerve fibers and protoplasm leakage along the path of the thick fibers. Proliferation of the glia, hyperemia of the vessels, and dilation of the perivascular space also occurred. The optic nerve was least affected. Degenerative phenomena in the neurons and proliferative phenomena in the glia were also observed in the visual region of the brain cortex. The histological results agree with those of electrophysiological studies.	Fel'dman and Vendilo (1973) C-5

TABLE III-7. DOGS--ACUTE EXPERIMENTAL EXPOSURE TO MeOH

Compound(s) and concentration(s) in mg/m³ (ppm)	Humidity/ temp.	Mode of exposure	Species/ strain/ age/weight	No. of test animals	No. of controls	Duration and frequency of exposure	Total length of experiment	Effects	Reference and rating
MeOH ~ 19,950 (15,000)			Dogs	3		22-24 h	22-24 h for two dogs, recovery period of 48 h for one dog	Blood levels of MeOH were 1,390-1,470 mg/100 g at end of exposure but dropped to 335 mg/100 g 48 h later in the one dog. Levels in tissue were in the 500-1,000 mg/100 g range at end of exposure but dropped to 200-400 mg/100 g 48 h later. The distribution of MeOH to tissues and fluids was closely related to the amount of water in the various body fluids and tissues.	Yant and Schrenk (1937) C-7
MeOH ~ 5,320 (4,000)			Dogs	2		12 h	12 h	Blood level of MeOH was 100 mg/100 g. Levels in tissue ranged from 95 mg/100 g in kidneys to 17 mg/100 g in adipose tissue. The distribution of MeOH to tissues and fluids was again closely related to the amount of water in the tissue or fluid.	Yant and Schrenk (1937) C-7
MeOH 390-720		Inhalation through nose mask while anesthetized	Dogs, mongrel, 8-22 kg	≥ 5		Not reported	Not reported	Retention of MeOH by respiratory tract increased with increased exposure concentration but was not affected by tidal volume.	Egle and Gochberg (1975) D-11
MeOH 400-600		Inhalation through tracheotomy while anesthetized	Dogs, mongrel, 8-22 kg	≥ 5		Not reported	Not reported	Lower respiratory tract MeOH retention rate was 64.6-68.2% with no relationship to ventilatory rate. Upper respiratory tract retention was 63.0-66.1% and related to ventilatory rates, with increased retention as the ventilatory rate increased.	Egle and Gochberg (1975) D-11
MeOH 400-600		Inhalation through nose mask while anesthetized	Dogs, mongrel, 8-22 kg	≥ 5		Not reported	Not reported	Total respiratory tract retention of MeOH was 81.2-88.4% over a range of ventilatory rates of 7-30/min. There was a statistically significant relationship between increased retention and higher ventilatory rates.	Egle and Gochberg (1975) D-11

TABLE III-8. DOGS--REPEATED DOSE EXPERIMENTAL EXPOSURE TO METHANOL (MeOH)

Compound(s) and concentration(s) in mg/m^3 (ppm)	Humidity/ temp.	Mode of exposure	Species/ strain/ age/weight	No. of test animals	No. of controls	Duration and frequency of exposure	Total length of experiment	Effects	Reference and rating
MeOH 5,320 (4,000)			Dogs	3		Continuous, 5 d	5 d for 2, recovery period of 120 h for one dog	Blood levels of MeOH after exposures were 317-570 mg/100 g but fell to 0 in the one dog 120 h later. Levels in tissues were in the 200-400 mg/100 g range at the end of exposure but 120 h later dropped to 0. The distribution of MeOH was closely related to the amount of water in the various body fluids and tissues.	Yant and Schrenk (1937) C-7

TABLE III-9. DOGS--CHRONIC EXPERIMENTAL EXPOSURE TO MeOH

Compound(s) and concentration(s) in mg/m^3 (ppm)	Humidity/ temp.	Mode of exposure	Species/ strain/ age/weight	No. of test animals	No. of controls	Duration and frequency of exposure	Total length of experiment	Effects	Reference and rating
MeOH ~ 13,300 (~ 10,000)		288 ft^3 inhalation chamber	Dogs	2	Served as own control	~ 3 min, 8 X/d for 100 consecutive d	~ 160 d	Regular increase in weight, no signs of discomfort, no significant changes in blood parameters, no eye pathology other than slight disk and fundi congestion on several occasions. Blood MeOH level at end of d was avg 6.5 and 14 mg/100 ml, level dropped to 0 by next d exposure 69% of time.	Sayers et al. (1944) C-7
MeOH ~ 599-665 (450-500)		Inhalation chamber, 288 ft^3 with eight air changes/h	Dogs	3 M, 1 F plus four pups born during exposure period	Used six control dogs; test dogs also served as own controls with 48-d observation period prior to exposure	8 h/d, 7 d/ wk, 379 d	~ 480 d	No symptoms or abnormal behavior. Weight remained steady or increased, except for weight changes associated with pregnancy. (Female bred to one of males during exposure period; gave birth to five pups.) Pups were normal; one pup died shortly after birth, its death attributed to smothering due to crowded conditions, others grew and developed normally. Blood chemistry and cell counts had no significant variations from pre-exposure levels. Regular ophthalmoscopic eye examinations were made and found a possible slight increase in congestion, but no edema, excavation, signs of atrophy, or indications of impaired vision. Blood sampled approximately monthly had avg MeOH levels of 7-15 mg/100 mL after 8-h exposure and < 5 mg/100 mL 16 h later before next MeOH exposure. MeOH blood levels appeared to increase during the 275th to 300th d of exposure reaching levels of 20-50 mg/ 100 mL. Blood MeOH levels also increased in some dogs when they were exercised on a treadmill, but decreased in others. No significant pathology observed in any organs.	Sayers et al. (1942) B-10

TABLE III-10. MONKEYS--ACUTE EXPERIMENTAL EXPOSURE TO MeOH

Compound(s) and concentration(s) in mg/m^3 (ppm)	Humidity/ temp.	Mode of exposure	Species/ strain/ age/weight	No. of test animals	No. of controls	Duration and frequency of exposure	Total length of experiment	Effects	Reference and rating
MeOH 6,650 (5,000)		1,000-L inhalation chamber	Cynomolgus monkeys, 2-3 kg	3-4	3-4	1 h	6 h	Little change in carboxyhemoglobin levels at 0, 2, 4, or 6 h postexposure.	Ciuchta et al. (1979) C-8

SECTION IV

EXPERIMENTAL HUMAN INHALATION EXPOSURE

This chapter describes acute laboratory human exposures to MeOH. A number of the studies presented in Table IV-1 are odor threshold determinations. Reported odor thresholds range from a high of 7,800 mg/m^3 to a much lower 4.3 mg/m^3, with values in between of 71, 133, and 1,500 mg/m^3. Varying levels of impurities in the MeOH samples tested may account for the discrepancy in results, since odor thresholds of compounds of low odor are greatly influenced by the presence of odorous impurities. Two studies measured urinary levels of MeOH during inhalation; another, cerebral cortex reflex activity; two investigated eye responses. Effects on eyes were found at 3.3 to 6.5 mg/m^3 levels but not at 1.8 to 2.4 mg/m^3, all far below the TLV limit of 260 mg/m^3 but above the upper limit of this report's recommended range of concern of 3.0 mg/m^3.

TABLE IV-1. HUMANS--ACUTE AND REPEATED DOSE EXPERIMENTAL INHALATION EXPOSURE TO MeOH

Compound and concentration in mg/m³ (ppm)	Mode of exposure	No. of test subjects	No. of controls	Duration and frequency of exposure	Total length of experiment	Effects	Reference and rating
MeOH 11,700	Inhalation by "sniffing" flask of MeOH	8 M, 8 F, ages 31-63		Tests repeated up to 5 X/d for an unspecified number of d for several mo	Not given	Clearly perceptible odor threshold measured at 760 torr and 20°C.	May (1966) D-5
MeOH 7,800	Inhalation by "sniffing" flask of MeOH	8 M, 8 F, ages 31-63		Tests repeated up to 5 X/d for an unspecified number of d for several mo	Not given	Just perceptible odor threshold measured at 760 torr and 20°C.	May (1966) D-5
MeOH ~ 1,995 (1,500)	Inhalation from air blender	3		Not given		Odor threshold.	Scherberger et al. (1958) D-10
MeOH 1,430	Small sealed room, 22.9 m³	1 (G.L.)*; same subject also exposed to 1,350, 732, and 700 mg/m³ levels at unknown intervals	Served as own control	1.6 h - 1st exposure, 2.9 h - 2nd exposure	~ 4.5 h	Urinary MeOH level increased steadily during both exposures; was 2.00 mg/100 mL at end of 1st exposure. During 2nd exposure, level at 1.6 h was 1.88 mg/100 mL, and 2.56 mg/100 mL at 2.5 h.	Leaf and Zatman (1952) A-7
MeOH 1,350	Small sealed room, 22.9 m³	1 (G.L.); same subject also exposed to 1,430, 732, and 700 mg/m³ levels at unknown intervals	Served as own control	3 h	~ 3.3 h	Urinary MeOH level increased steadily during exposure; was 1.46 mg/100 mL** at 1.6 h and 2.06 mg/100 mL at 2.5 h.	Leaf and Zatman (1952) A-7

* Subject's initials.

** Urinary MeOH levels reported by Leaf and Zatman (1952) are corrected for the control value, the level found on entry into the exposure room prior to any MeOH exposure.

(continued)

TABLE IV-1. (continued)

Compound and concentration in mg/m^3 (ppm)	Mode of exposure	No. of test subjects	No. of controls	Duration and frequency of exposure	Total length of experiment	Effects	Reference and rating
MeOH 1,230	Small sealed room, 22.9 m^3	1 (L.J.Z.); same subject also exposed to 655 and 732 mg/m^3 levels at unknown intervals	Served as own control	2.5 h	~ 3 h	Urinary MeOH level increased steadily during exposure; was 1.90 mg/100 mL at 1.6 h, and 2.54 mg/100 mL at 2.5 h.	Leaf and Zatman (1952) A-7
MeOH 732	Small sealed room, 22.9 m^3	1 (L.J.Z.); same subject also exposed to 1,230 and 655 mg/m^3 levels at unknown intervals	Served as own control	4 h	4 h	Urinary MeOH level increased steadily during exposure; was 0.94 mg/100 mL at 1.6 h, 1.32 mg/100 mL at 2.5 h, and, at the end of the exposure, ~ 2.2 mg/100 mL.	Leaf and Zatman (1952) A-7
MeOH 732	Small sealed room, 22.9 m^3	1 (G.L.); same subject also exposed to 1,430, 1,350, and 700 mg/m^3 levels at unknown intervals	Served as own control	4 h	4 h	Urinary MeOH level increased steadily during exposure; was 0.77 mg/100 mL at 1.6 h, 1.05 mg/100 mL at 2.5 h, and, at the end of exposure, ~ 1.8 mg/100 mL.	Leaf and Zatman (1952) A-7
MeOH 700	Small sealed room, 22.9 m^3	1 (G.L.); same subject also exposed to 1,430, 1,350, and 732 mg/m^3	Served as own control	3.1 h	~ 3.1 h	Urinary MeOH level increased steadily during exposure; was 0.56 mg/100 mL at 1.6 h, and 0.78 mg/100 mL at 2.5 h.	Leaf and Zatman (1952) A-7

(continued)

TABLE IV-1. (continued)

Compound and concentration in mg/m³ (ppm)	Mode of exposure	No. of test subjects	No. of controls	Duration and frequency of exposure	Total length of experiment	Effects	Reference and rating
MeOH 655	Small sealed room, 22.9 m³	1 (L.J.Z.); same subject also exposed to 1,230 and 732 mg/m³ levels at unknown intervals	Served as own control	3.3 h	~ 3.5 h	Urinary MeOH level increased steadily during exposure; was 0.76 mg/100 mL at 1.6 h, 1.03 mg/100 mL at 2.5 h, and, at the end of the exposure, ~ 1.4 mg/100 mL.	Leaf and Zatman (1952) A-7
MeOH 298-337	Room, 64.3 m³	3 M, ages 31-56		8 h/d for 4 consecutive d (urine collected at 2-h intervals)	~ 96 h	No accumulation of MeOH in the body; urine levels returned to normal before the next exposure.	Sedivec et al. (1981) A-10
MeOH 300	Room, 64.3 m³	4 M, ages 31-56	17 M 14 F	8 h, once	24 h	Lung retention independent of lung ventilation and duration of exposure. Urine MeOH level increased from norm of ~ 0.7 mg/L to 9.5 mg/L at 8 h and returned to normal 16 h after end of exposure.	Sedivec et al. (1981) A-10
MeOH 231-251	Room, 64.3 m³	5 M, ages 31-56		4 h/8 h, in 2-h periods with exposures chosen to cover all possible combinations of early, late, and alternate exposure/nonexposure	8 h	MeOH in urine was affected by "pauses" in exposure - level decreased. Short-term urine samples did not accurately reflect level of total exposure in this type of intermittent exposure.	Sedivec et al. (1981) A-10
MeOH 205	Room, 64.3 m³	4 M, ages 31-56	17 M 14 F	8 h, once	24 h	Lung retention independent of lung ventilation and duration of exposure. Urine MeOH level increased from norm of ~ 0.7 mg/L to 6.6 mg/L at 8 h and returned to normal 16 h after end of exposure.	Sedivec et al. (1981) A-10
MeOH 200 Ethanol 514	Room, 64.3 m³	3 M, ages 31-56		8 h		No inhibitory effect from ethanol on level of MeOH in urine.	Sedivec et al. (1981) A-10

(continued)

TABLE IV-1. (continued)

Compound and concentration in mg/m³ (ppm)	Mode of exposure	No. of test subjects	No. of controls	Duration and frequency of exposure	Total length of experiment	Effects	Reference and rating
MeOH 199	Room, 64.3 m³	4 M, ages 31-56; 2 limited liquid intake, 2 increased it; subjects switched roles 2nd wk		8 h, once/wk	2 wk	MeOH in urine remained the same regardless of volume excreted. (Indicates rate of excretion of MeOH from the body is dependent on intake of liquids.)	Sedivec et al. (1981) A-10
MeOH 133 (100)	500 ft³ inhalation chamber	Four trained odor panelists	None	Duration not given, ≥ 20 min between tests	Not given	Odor threshold determined as level at which panelists recognized the odor.	Leonardos et al. (1969) A-11
MeOH 118	Room, 64.3 m³; 19 5-min exercise periods on a bicycle ergometer	4 M		8 h		Lung ventilation increased on avg. of 2.56 X during exercise. The total air volume inspired during the 8-h test was 1.45 X higher than normal. The basic correlation between MeOH dose and MeOH concentration in whole workshift urine (derived at resting lung ventilation) was also valid where subjects performed physical work and had enhanced lung ventilation.	Sedivec et al. (1981) A-10
MeOH 103	Room, 64.3 m³	4 M, ages 31-56	17 M 14 F	8 h, once	24 h	Lung retention independent of lung ventilation and duration of exposure. Urine MeOH level increased from norm of ~ 0.7 mg/L to 3.2 mg/L at 8 h and returned to normal 10 h after end of exposure.	Sedivec et al. (1981) A-10
MeOH 99 Ethanol 996	Room, 64.3 m³	3 M, ages 31-56		8 h (14 d after exposure to 200 mg MeOH/m³ level)		No inhibitory effect from ethanol on level of MeOH in urine.	Sedivec et al. (1981) A-10
MeOH 70.9 (53.3)	Odor fountain	Trained odor panel with unreported number of subjects	Not given	20 min	20 min	Odor recognition threshold, concentration at which 100% of the odor panel defined the odor as being representative of the odorant being studied.	Hellman and Small (1974) A-3

(continued)

TABLE IV-1. (continued)

Compound and concentration in mg/m^3 (ppm)	Mode of exposure	No. of test subjects	No. of controls	Duration and frequency of exposure	Total length of experiment	Effects	Reference and rating
MeOH ~ 19.95 (4.26)	Odor fountain	Trained odor panel with unreported number of subjects		20 min	20 min	Absolute odor threshold, concentration at which 50% of the odor panel observed an odor.	Hellman and Small (1974) A-3
MeOH 4.3-11	The author states only that the method to measure the odor threshold was that recommended by the "Committee on Sanitary Protection"		13	Not given	Not given	The range represents the minimal methanol concentrations perceived by the individual subjects.	Chao Chen-Tsi (1959) A-8 (human) B-8 (animal)
MeOH 5.7-6.5		3	Served as own controls		15 min pure air followed by 5 min MeOH-air; "several times" (probably 14 or 15)	Pattern of dark adaptation changed more strikingly from that of the controls than seen at lower concentrations.	Chao Chen-Tsi (1959) A-8 (human) B-8 (animal)
MeOH 4.3-4.7	Not given	3	Served as own controls		15 min pure air followed by 5 min MeOH-air; "several times" (probably 14 or 15)	Pattern of dark adaptation was markedly altered from that of the controls.	Chao Chen-Tsi (1957) A-8 (human) B-8 (animal)
MeOH 4.5		25, ages 18-40		Not given	Not given	Odor threshold.	Ubaydullayev (1968) B
MeOH 4.11		3, ages 18-25	Served as own control	One test exposure/d, 15-20 min	Not given	Eye adaptation to the dark or sensitivity to light was determined. Eye sensitivity was decreased.*	Ubaydullayev (1968) A-8

* Interpretation of effect uncertain because of limited information supplied by paper.

TABLE IV-1. (continued)

Compound and concentration in mg/m^3 (ppm)	Mode of exposure	No. of test subjects	No. of controls	Duration and frequency of exposure	Total length of experiment	Effects	Reference and rating
MeOH 3.3-3.7	Not given	3	Served as own controls	Not given	15 min pure air followed by 5 min MeOH-air; "several times" (probably 14 or 15)	The threshold of reflex action on light sensitivity. The pattern of dark adaptation was not greatly different from that of the controls.	Chao Chen-Tsi (1959) A-8 (human) B-8 (animal)
MeOH 3.06-3.52	Not given	1, ages 18-25	Served as own control	One test exposure/d, 15-20 min	Not given	Eye adaptation to the dark or sensitivity to light was determined. Lower concentration was no effect level. At higher concentration sensitivity changed, first increasing, then decreasing, and finally returning to near normal.	Ubaydullayev (1968) A-8
MeOH 1.8-2.4	Not given	3	Served as own controls	Not given	15 min pure air followed by 5 min MeOH-air; "several times" (probably 14 or 15)	No difference in the pattern of dark adaptation from that of the controls.	Chao Chen-Tsi (1959) A-8 (human) B-8 (animal)
MeOH 1.46	Not given	6 (subjects selected for olfactory sensitivity)	Served as own control	Not given	Not given	Significant change in alpha-rhythm amplitude of cerebral cortex reflex activity in all subjects.	Ubaydullayev (1968) A-8
MeOH 1.17	Not given	4 (subjects selected for olfactory sensitivity)	Served as own control	Not given	Not given	Significant change in alpha-rhythm amplitude of cerebral cortex reflex activity in two subjects.	Ubaydullayev (1968) A-8

(continued)

TABLE IV-1. (continued)

Compound and concentration in mg/m^3 (ppm)	Mode of exposure	No. of test subjects	No. of controls	Duration and frequency of exposure	Total length of experiment	Effects	Reference and rating
MeOH 1.01		6 (subjects selected for olfactory sensitivity)	Served as own control	Not given	Not given	No effect on alpha-rhythm amplitude of cerebral cortex reflex activity.	Ubaydullayev (1968) A-8

SECTION V

OCCUPATIONAL EXPOSURES AND HUMAN CASE REPORTS

This chapter describes studies of occupational exposure to MeOH and contains a brief review of the numerous human case histories reported in the literature. The occupational studies (Table V-1) are not particularly useful in establishing a range of concern for MeOH exposure because of poor control, lack of health effect information, or confounded exposure. One study found 11 workers who developed vision defects from exposure to 1.6 to 10.9 mg MeOH/m^3, but this is an isolated case. Headaches were reported by office workers exposed to 20 to 500 mg MeOH/m^3, and also by two workers in another office where the MeOH exposure was much lower (~ 3.2 to 6.5 mg/m^3) but confounded by the presence of toluene and CO.

Almost all of the case histories are early publications that give limited information, especially as to level of exposure. Because of the limited data, these cases are difficult to tabulate and contribute little toward quantifying a range of concern, but are of interest in that they definitely establish the toxicity of MeOH to humans through all routes of exposure.

Some of the earliest inhalation cases involved occupational exposure of workmen shellacking the interiors of beer vats. Wood and Buller (1904), Wood (1912), Carhart (1908), Herbert (1902), Jelliffe (1905), Tyson (1912), and Hamilton (1925) all report cases of workmen entering poorly ventilated beer vats and using varnish made with MeOH. These reports indicate that a number of workmen collapsed and either died or were left partially or totally blind as a result. These papers--as well as ones by De Schweinity (1901), Stricker (1908), and Hawes (1905) that reported other cases of painters and varnishers harmed by MeOH exposure--established the toxicity of MeOH by inhalation years ago. Descriptions of cases are limited; but, in general, the initial signs of toxicity were delayed until 1 day or more after the initial exposure when the workmen experienced various symptoms such as headaches, nausea, and failing vision.

Tyson (1912) reports the cases of two women who worked polishing lead pencils using varnish made with MeOH. Both had failing vision and other symptoms that cleared somewhat when leaving the workplace and getting fresh air.

The hat stiffeners were another early occupation in which workers suffered from MeOH exposure. Baskerville (1913) reported the cases of 15 such workers who had various health effects and diminished vision from MeOH exposure while working from 6 months to 32 years with MeOH. The testimony of

Danburg, Connecticut, hatters before Congress that 75 of their number had suffered health effects and/or impairment of sight contributed to the passage of a measure that made revenue-free denatured grain alcohol available for industrial use.

Another case of toxic occupational exposure to MeOH involved workers manufacturing artificial flowers. Twenty women were reported to have conjunctivitis and skin inflammation from their use of dyes dissolved in MeOH. Other occupational cases involved a man using a liquid shoe dye (Robinson, 1918), a worker in a nitrocellulose plant, and a chemical-pharmaceutical factory worker (NIOSH, 1976).

A few case histories clearly involving skin absorption have been reported, although some inhalation may have occurred in each case. One involved a painter who spilled a gallon of MeOH down his leg soaking his clothes and shoe. He let them dry on him and within a few days blindness developed (Hamilton, 1925). Wood and Buller (1904) report the case of a woman who bathed her head and face daily with MeOH for weeks. Her vision diminished until the MeOH applications were discontinued. Other cases involved 21 children who had cloths soaked in MeOH applied to their abdomens and held in place by rubber pants. Signs of intoxication developed in 1 to 13 h; 12 died, the others recovered without any permanent damage (NIOSH, 1976).

Literally hundreds of cases of poisoning by ingesting MeOH have been reported. By 1913, Baskerville had listed a series of 720 reported cases of which ~ 50% were fatal and ~ 25% resulted in permanent impairment of vision or blindness. Most of these cases involved drinking bootleg or cheap alcoholic beverages that had been adulterated with the cheap, readily available wood alcohol. Dose information is limited, but Baskerville reports a case where total blindness resulted from drinking 0.5 fluid ounce wood alcohol (~ 15 mL) and another case of death from 0.75 ounce (~ 22 mL). These case histories also indicate that extreme variability of individual sensitivity to MeOH exists as other cases were reported of individuals consuming four or more ounces of MeOH and recovering completely (Baskerville, 1913).

Cooper and Kini (1962) report that during the prohibition period in the United States there were 400 fatalities due to MeOH ingestion in 7 months. They also quote a 1950 report by Zohl that estimates 6% of all blindness in the Armed Forces during World War II was caused by MeOH ingestion. Other papers that detail later case histories but with limited dose information are Menne (1938), Closs and Solberg (1970), McLean et al. (1980), and McMartin et al. (1980).

Several major outbreaks of MeOH poisoning have been reported. Kane et al. (1968) reported on 18 cases in Kentucky. Cooper et al. (1952), Benton and Calhoun (1953), and Bennett et al. (1953) reported on the Atlantic epidemic of 323 cases with 41 deaths. Individuals had consumed illicit whiskey of 30 to 40% MeOH. Onset of symptoms varied from 40 min to 72 h and included visual disturbances, headache, and gastrointestinal disturbances. Again, great individual variable was evidenced--one individual died from ingesting 15 mL, another individual survived 500 mL.

TABLE V-1. STUDIES OF OCCUPATIONAL EXPOSURE TO MeOH

Compound(s) and Concentration(s) in mg/m³ (ppm)	Population Group			Effects	Remarks	Reference and Rating
	Description	Exposed	Controls			
MeOH 754-1,640 (hand unloading and crushing of cholesterol, 1 h each shift)	Workers in a plant manufacturing emulgents from cholesterol	2	None	Urine sampled during work shift and 8 h afterwards at 2-h intervals. MeOH in urine during work shift ranged from 14.4-36.4 mg/L, with 1st level of one worker at only 4.8 mg/L. After work, levels ranged from 0.36 to 3.96 mg/L with highest levels 6 and 8 h after work shift.	No health effects measured. Useful, however, for correlation of environmental exposures to physiologic measurements in exposed persons. Inadequate numbers to be convincing and no real controls are present.	Dutkiewicz and Blochowicz (1967) C-6
MeOH 45-894 (short-term exposures for 0.25-5 h during certain processes in production cycle)		5		Urine MeOH levels during work shift ranged from 0.83 to 22.5 mg/L. After work levels ranged from 0.046-1.37 mg/L.	No health effects measured. Useful, however, for correlation of environmental exposures to physiologic measurements in exposed persons. Inadequate numbers to be convincing and no real controls are present.	Dutkiewicz and Blochowicz (1967) C-6
MeOH 59-270 (longer-term exposures during regular production for most of 8 h shift)		6		Urine MeOH levels during work shift ranged from 0.09-12.3 mg/L with most < 4 mg/L; after work levels ranged from 0.07-1.37 mg/L with most < 1 mg/L.	No health effects measured. Useful, however, for correlation of environmental exposures to physiologic measurements in exposed persons. Inadequate numbers to be convincing and no real controls are present.	Dutkiewicz and Blochowicz (1967) C-6
MeOH ~ 20-499 (15-375)	Office workers	Not given	None	Workers reported frequent, recurrent, persistent headaches, especially in cooler weather when windows were closed. Workers closer to the spirit duplicating machines and those actually operating them had most severe symptoms.	No quantification of health effects nor numbers of persons affected. Air measurements taken are not related to any measure of physiologic parameters. It rates as an anecdotal case report.	Kingsley and Hirsch (1954-1955) D-3

(continued)

TABLE V-1. (continued)

Compound(s) and Concentration(s) in mg/m^3 (ppm)	Population Group			Effects	Remarks	Reference and Rating
	Description	Exposed	Controls			
MeOH ~ 113-178 (85-134) Mean of air concentration in three locations in shop; range over 16.5-h sampling period was < 10 to 650 ppm	Workers in printing shop	20	15-36	Blood and urine levels of formic acid were compared between workers and controls. In blood, mean value of controls in the morning was 5.6 ± 4.5 mg/L, and, in the afternoon, 4.9 ± 4.2 mg/L. In the workers, the mean value in the morning was 3.2 ± 2.4 mg/L, and, in the afternoon, 7.9 ± 3.4 mg/L. The controls had either lower or slightly higher (0.6 mg/L) afternoon values compared to morning values, whereas all the workers had higher afternoon values. Both the increased level in the afternoon and the differences between the control and workers' afternoon values are significant. In urine, the mean value of controls in the morning was 11.9 ± 6.4 mg/L, and, in the afternoon, 11.7 ± 5.6 mg/L. In the workers, the mean morning value was 13.1 ± 3.9 mg/L, and, in the afternoon, 20.2 ± 7.0 mg/L. Same significant increase as with blood in workers' afternoon values over morning or control values. Analysis of MeOH content of alveolar air of exposed worker showed slightly significant increase between morning and afternoon levels. Angerer et al. (1977) compared air levels of MeOH in the three locations to mean workers' formic acid levels in urine and MeOH in alveolar air and found no dose relationship to measured levels.	Cross-sectional study of measured air exposure to MeOH and effect as measured by blood and urine formic acid level. No health effects were measured. Controls revealed wide variability of formic acid concentrations in blood (0 to 20 mL) and urine. Unfortunately, information was not obtained on factors which influence formic acid levels (i.e., diet, cigarette smoking status, etc.). Stratification on these parameters may have permitted a better understanding of the use of these measures in epidemiological or occupational studies. Useful since, although no correlation was present between air exposure levels, there was a significant difference over time (i.e., beginning at end of shift) as compared to controls.	Baumann and Angerer (1979); Angerer and Lehnert (1977); Angerer et al. (1977) B-9

(continued)

TABLE V-1. (continued)

Compound(s) and Concentration(s) in mg/m³ (ppm)	Population Group			Effects	Remarks	Reference and Rating
	Description	Exposed	Controls			
HCHO 5-78 MeOH 2.1-7.5 EtOH 47.5-110	Workers in the formalin department of a sheepskin dyeing factory	99 F; 25-40-y-old; worked for 5-20 y	84 F in other shops, free of HCHO vapors	Complaints of persistent headache, vertigo, irritability, and tendency to weep. Skin temperature was measured on the forehead, chest, and forearm, and the variations between the left and right sides of the body reported. The incidence of physiological thermal asymmetry (a difference of 0.1-0.5°C) before work was 43.3% in the exposed group and 27.2% in the controls. The incidence of pathological thermal asymmetry (0.6-2.2°C) before work was 48.4% in the test group and 3.0% in the controls. After work, the physiological asymmetry was about equal in both groups (33% versus 34.5% in the controls), and the pathological asymmetry increased to 60% in the test group, compared to 8.6% in the control group. The authors consider this evidence of adverse effects on the CNS, including the thermoregulatory center.	Essentially a prospective design. The exposure was confounded by the presence of ethanol (EtOH) and MeOH vapors, and monochloroacetic acid. Comparability of the controls is not discussed.	Kamchatnov and Gayazova (1971) C-8
MeOH ~ 3.2-6.5 (2.4-4.9) Toluene (0.6-1.0) CO (< 5.0) MeOH and toluene were generated by even limited use of the copying machine	Workers in a business office	2	None	Workers complained of headaches, dry or sore throats; periods of illness seemed to correlate with operation of office copying machine.	Confounded exposure. Health effects poorly described. No controls.	Fannick (1980) C-5

(continued)

TABLE V-1. (continued)

Compound(s) and Concentration(s) in mg/m^3 (ppm)	Population Group: Description	Exposed	Controls	Effects	Remarks	Reference and Rating
During injection, at the pump: HCHO 0.4-0.5 (MAC = 0.5) MeOH 2.6-10.3 (MAC = 5.0) During cleanup work: HCHO 0.2-0.13 MeOH, 0.14-0.8	Workers in coal mines whose air content of dust and methane was controlled by injecting a urea-HCHO resin into the coal-bearing strata. Donetes Coal Basin, 1973-1975. (The major effect of the treatment was the lowering of the dustiness by 32%, but the particles 2.5-5 μm in size still comprised 70-75% of the total dust particles.)	Not given	Workers in untreated mines	Workers examined in the course of 1-3 mo after the treatment and 4 mo later did not show any differences from the norms or from the control group in the following indexes: arterial pressure, pulse rate, CO_2 content in air exhaled at rest, vital capacity of the lungs, muscular work capacity, rate of processing information, and blood analysis values.	The exposure is confounded. The number of persons and symptoms are not quantified.	Gadzhiev et al. (1977) D-4
MeOH 1.6-10.9	Workers handling material wet with 35-40% MeOH in a nitrocellulose manufacturing plant	23; 16 had 0.5-3 y exposure, seven had 3.5-6 y exposure	None	One worker who had worked in the area exposed to MeOH for 4 y developed symptoms of pleura irritation and vision defects. These cleared during a 6-wk leave. After 2 wk back at work, vision failed again, but was restored within 15 mo. None of the other workers had any symptoms of MeOH toxicity.	Uncontrolled descriptive study of workers in a nitrocellulose manufacturing plant. Essentially a case report. Exposure times and levels were taken, but are not well correlated to health effects.	Humperdinck (1941) C-6

ANNOTATED BIBLIOGRAPHY

7-106 ACGIH, American Conference of Governmental Industrial Hygienists. 1971. Documentation of the Threshold Limit Values for Substances in Workroom Air, 3rd ed. ACGIH, Cincinnati, Ohio. pp. 155-156.

C--. Brief review of MeOH toxicity data.

ACGIH, American Conference of Governmental Industrial Hygienists. 1980. TLVs. Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Air Adopted by ACGIH for 1980. Publications Office, ACGIH, Cincinnati, Ohio. p. 22.

A--. Recommends time-weighted TLV of 260 mg MeOH/m^3 and short-term exposure limit of 310 mg/m^3.

7-145 ACT, Advisory Center on Toxicology. 1960. ACT Report No. 35; Report on Methanol. In: Toxicity Evaluation of Potentially Toxic Materials Part III. National Academy of Sciences-National Research Council, Washington, D.C. 22 pp.

D--. Brief review of MeOH toxicity with recommended limits for persons exposed to MeOH from spirit duplicating machine, for 1 h exposure every 24 h, a limit of 500 ppm; 200 ppm limit for 2 h exposure every 24 h.

7-143 AIHA, American Industrial Hygiene Association. 1978. Hygienic Guide Series; Methyl Alcohol. American Industrial Hygiene Association, Akron, Ohio.

D--. Summary of various exposure standards such as TLV's, toxicity data, recommended industrial and medical treatment.

7-001 Angerer, J., and G. Lehnert. 1977. Occupational Exposure to Methanol. Acta. Pharmacol. Toxicol. Suppl. 41(2):551-556.

B-9. Some of same data presented in Baumann and Angerer (1977) [7-005], same study of print shop workers exposed to MeOH. Presents the data on formic acid levels in urine and expired air of workers compared to controls.

7-002 Angerer, J., A. Manz, G. Lehnert, and D. Szadkowski. 1977. Formic Acid in the Urine and Methanol Concentration in the Alveolar Air in Low Pressure Workers Exposed to Methanol. Med. Monatsschr. 31(1):36-39 (Ger).

B--. Same study as Angerer and Lehnert (1977) [7-001] and Baumann and Angerer (1979) [7-005] on workers exposed to MeOH in a print shop. Presents data on formic acid level in urine and MeOH in alveolar air broken down by work area with average exposure to MeOH reported for each area.

7-004 Baskerville, C. 1913. Second Report of the Factory Investigating Commission on the Chemistry, Technology and Pharmacology of the Legislation Pertaining to Methyl Alcohol. Volume 2. J. B. Lyon Company, New York, New York. pp. 921-1042.

C--. Summary of production, uses and toxicity of MeOH. Brief case histories of 15 persons affected by MeOH while working in stiffening departments of hat factories are presented as well as listing of ~ 75 others injuried by the same type of exposure. Eye inflammation and loss of vision were reported in majority of cases.

7-005 Baumann, K., and J. Angerer. 1979. Occupational Chronic Exposure to Organic Solvents. VI. Formic Acid Concentration in Blood and Urine as an Indicator of Methanol Exposure. Int. Arch. Occup. Environ. Health 42(3-4):241-249.

B-9. Study of workers in printing shop exposed to MeOH at levels of ~ 10 to 650 ppm (mean for 3 locations 85-134 ppm). Formic acid levels in blood and urine were measured in the morning and again in the afternoon to see if there was an increase during exposure to MeOH. Formic acid levels did significantly increase during exposure both compared to morning levels in the workers and in comparison to levels in control persons. Authors concluded urine and especially blood levels of formic acid can be checked for indication of exposure to MeOH but is not accurate enough to monitor occupational exposure because of individual variability.

7-081 Bennett, I. L., F. H. Cary, G. L. Mitchell, Jr., and M. N. Cooper. 1953. Acute Methyl Alcohol Poisoning--A Review Based on Experiences in an Outbreak of Cases. Medicine 32:431-463.

C--. Review of toxicity of MeOH to humans through ingestion. Description of medical cases of individuals involved in the 1951 Atlanta incident involving bootleg whiskey adulterated with MeOH. In-depth clinical discussion of the cases as well as review of related literature.

7-159 Benton, C. D., Jr., and F. P. Calhoun. 1953. The Ocular Effects of Methyl Alcohol Poisoning: Report of a Catastrophe Involving 320 Persons. Am. J. Ophthalmol. 36:1677-1685.

B-8. In depth report on eye damage resulting from the Atlanta poisoning incident involving 323 persons poisoned by bootleg whiskey adulterated with MeOH. Majority experienced visual disturbance ranging from seeing spots to complete blindness. Most of survivors (41 died) regained partial or complete visual acuity.

7-126 Bertarelli, E. 1934. Routine Hazards of Methyl Alcohol. Ann. Igiene. 44:729-731 (Ital).

D--. Brief review of the uses, and just a mention that MeOH is toxic via several routes. Mentions one accident when hundreds were temporarily "afflicted" (no symptoms), but only ~ 10 died.

7-127 Birch-Hirschfeld, A. 1901. Experimental Studies of the Pathogenesis of Methyl Alcohol Amblyopia. [Albrect von Graefe's] Arch. Ophthalmol. 52:358-383 (Ger).

D--. Optic changes were described after rabbits and hens were dosed orally with 50% aqueous solutions containing a total of ≦ 287.5 mL over ≦ 25 d.

7-102 Browning, E. 1965. Toxicity and Metabolism of Organic Solvents. Elsevier Publishing Co., Amsterdam, The Netherlands. pp. 311-323 and 401-411.

D--. General review of MeOH and its toxicity to animals and humans, effects on different organs, symptoms of poisoning, and treatment.

7-121 Carhart, W. M. 1908. Toxic Amblyopia from Wood Alcohol. Am. Med. 14:176-177.

B-5. Report of one human case involving a worker exposed to unknown concentration MeOH while shellacking a beer vat for 3 wk. Blindness developed within 2 d and only limited vision was regained.

7-162 Carroll, R. B. 1970. Analysis of Alcoholic Beverages by Gas-Liquid Chromatography. Quart. J. Studies Alc. Suppl. No. 5:6-19.

D--. Study identified MeOH in a number of beverage alcohols, at levels from 0.26 to 105.5 g/100 L.

7-007 Chao, Chen-Tsi. 1959. Materials on the Hygienic Standardization of the Maximally Permissible Concentration of Methanol Vapors in the Atmosphere. Gig. Sanit. 24(10):7-12 (Russ).

A-7, Human, B-7, Animal Tests. The odor threshold ranged from 4.3 to 11 mg MeOH/m^3 for 13 human subjects. With 3 human subjects, changes in light sensitivity were noted at 3.3-3.7 mg MeOH/m^3. Rats exposed to 50 mg/m^3 for 12 h/d for 3 mo showed changes in chronaxies of the flexors and extensors, changes in the trachea somewhat more expressed than those of the bronchi and lungs, and deformation of the brain cortical neurons. The only abnormalities seen from 10 rats exposed similarly to only 1.77 mg MeOH/m^3 was deformation of the dendrites in one rat brain.

7-009 Ciuchta, H. P., G. M. Savell, and R. C. Spiker, Jr. 1979. The Effect of Alcohols and Toluene upon Methylene Chloride-Induced Carboxyhemoglobin in the Rat and Monkey. Toxicol. Appl. Pharmacol. 49(2):347-354.

C-8. Exposure of rats and monkeys to 5,000 ppm MeOH for 1 h caused little or no effect on carboxyhemoglobin levels.

7-083 Clay, K. L., R. C. Murphy, and W. D. Watkins. 1975. Experimental Methanol Toxicity in the Primate--Analysis of Metabolite Acidosis. Toxicol. Appl. Pharmacol. 34(1):49-61.

D--. Pigtail monkeys (Macaca nemestrina) are a suitable model for human methanol toxicity with 4 g MeOH/kg (~ LD_{50}) producing marked acidosis, which could be accounted for primarily by formate.

7-165 Closs, K., and C. O. Solberg. 1970. Methanol Poisoning. J. Am. Med. Assoc. 211(3):497-499.

C--. Case history of man hospitalized in coma with indications of MeOH poisoning from adulterated alcohol ingested 18 h earlier. After treatment full recovery was made.

7-084 Cook, W. A. 1945. Maximum Allowable Concentrations of Industrial Atmospheric Contaminants. Ind. Med. 14(11): 936-946.

D--. Early listing of MAC's from 8 state and federal agencies. The allowable concentration for MeOH ranged from 100-200 ppm.

7-085 Cooper, J. A., and M. M. Kini. 1962. Biochemical Aspects of Methanol Poisoning (editorial). Biochem. Pharmacol. 11:405-416.

D--. Review of toxicity of MeOH, metabolism, and mechanism of effect.

7-086 Cooper, J. R., and P. Felig. 1961. The Biochemistry of Methanol Poisoning II. Metabolic Acidosis in the Monkey. Toxicol. Appl. Pharmacol. 3(2):202-209.

C-9. Monkeys were given oral doses of 0.48-9.0 g MeOH/kg of body wt. LD_{50} was 7.9 g/kg. No obvious effects at < 5 g/kg. Ataxia, weakness, lethargy, and transient coma occurred at higher doses. Those that survived recovered within 24 h, for others, coma continued to death. Only moderate increase in excretion of organic acids in urine measured.

7-155 Cooper, M. N., G. L. Mitchell, I. L. Bennett, and F. H. Cary. 1952. Methyl Alcohol Poisoning: An Account of the 1951 Atlanta Epidemic. J. Med. Assoc. Ga. 41:48-51.

C--. Brief description of cases of MeOH poisoning from adulterated bootleg whiskey, description of hospital emergency care and treatment, symptoms of patients, and response to treatment. Situation involved 323 patients with 41 deaths.

7-011 De Schweinitz, G. E. 1901. A Case of Methyl-Alcohol Amaurosis, the Pathway of Entrance of the Poison Being the Lungs and the Cutaneous Surface. Ophthalmic. Rec. 10:289-296.

C--. Case history of man exposed daily for 3 mo and intermittently over a 2-y period to MeOH-based varnish. After a sudden illness without typical signs of MeOH toxicity other than blurred vision, he suffered total loss of vision.

7-087 Dutkiewicz, T., and A. Blockowicz. 1967. Evaluation of Exposure to Methanol in View of Field Studies. Med. Pr. 18:132-141 (Pol).

C-6. Workers in an emulgent manufacturing plant were exposed to MeOH at 3 different levels and time frames. Exposure was compared to MeOH levels measured in urine during work shift and 8 h later. Exposures were to 754-1640 mg/m^3 for 1 hr, 45-894 mg/m^3 for 0.25-5 h, 59-270 mg/m^3 for 8 h. Urine MeOH levels increased directly with increased exposure.

7-146 Dutkiewicz, B., J. Konczalik, and W. Karwacki. 1980. Skin Absorption and Per Os Administration of Methanol in Men. Int. Arch. Occup. Environ. Health 47(1):81-88.

B-11. Rate of absorption of MeOH by human skin was 0.131-0.291 mg $MeOH/cm^2/min$.

7-013 Egle, J. L., Jr., and B. J. Gochberg. 1975. Retention of Inhaled Isoprene and Methanol in the Dog. Am. Ind. Hyg. Assoc. J. 36(5): 369-373.

D-11. Exposure of dogs to ~ 400-700 mg/m^3 MeOH for unknown period of time. Relationship found between increased retention of MeOH by respiratory tract and increased exposure concentration, also increased retention at higher ventilatory rates.

7-129 Eisenberg, A. A. 1917. Visceral Changes in Wood Alcohol Poisoning by Inhalation. Am. J. Publ. Health 7(9):765-771.

C-7. Rabbits were exposed in a ~ 0.1 m^3 chamber to air saturated with 0.5 and 1.0 ounce of MeOH for 15 min, 3 x/d. At the 1.0-ounce level, 3 of 6 animals died, others (9) were examined after 2-10 mo exposure and found to have lesions of brain, optic nerve, liver, kidney, muscles, and especially cardiac muscles.

7-157 Eriksen, S. P., and A. B. Kulkarni. 1963. Methanol in Normal Human Breath. Science 141(3581):639-640.

D--. MeOH levels in normal human breath ranged from 0.06 to 0.49 μg/L.

7-014 Ermolenko, A. E., V. B. Pankova, N. G. Popova, and S. N. Khmara. 1975. Some Problems of Occupational Hygiene and the Health Status of Core-Molders Working in a Foundry of a Modern Motor Car Manufacturing Plant. Gig. Tr. Prof. Zabol. No. 8:11-14 (Russ); English translation available from John Crerar Library, Chicago, Illinois. Order No. 76-12470-06J.

D-6. Study of foundry workers where furan bonding agents are utilized exposing the workers to a mixture of 0.6 to 10.0 mg $HCHO/m^3$, 1.3 to 30.0 mg $MeOH/m^3$, 0.01 to 0.5 mg furfural/m^3, 0.2 to 15.0 mg NH_3/m^3, 0 to 22.5 mg furyl alcohol/m^3, trace to 12.5 mg CO/m^3, and 0.03 to 0.2 mg P_4O_{10}/m^3. Workers were questioned concerning health and 68% reported frequent angina; 20.4%, dryness of throat, nose and hoarseness; and 25%, nasal obstruction. Workers when examined and compared to control group had increased frequency of respiration; 40-54% had decreased maximal velocity of air flow exhalation; 26-51%, chronic rhinitis; 46%, chronic tonsillitis; and 32%, elevated olfactory threshold.

7-163 Fannick, N. 1980. Health Hazard Evaluation Determination Report HE-78-81-658. PB80-169832. National Technical Information Service, Springfield, Virginia. 10 pp.

C-5. Study of office where workers complained of illness from operation of copying machine. Air contained 2.1-4.9 ppm MeOH, 0.6-1.0 ppm toluene, and < 5.0 ppm CO. Workers reported headaches and dry or sore throats with the periods of illness correlating with the operation of the copying machine. Study found that even limited use of copier generated MeOH and toluene.

7-015 Fel'dman, N. G., and M. V. Vendilo. 1973. Effect of Aliphatic Alcohols on the Visual Analyzer. Neurohistological Study. Gig. Tr. Prof. Zabol. No. 3:55-56 (Russ).

C-5. Rabbits exposed for 4 h/d for 6-7 mo to the MAC's of methanol (5 mg/m^3), hexanol, heptanol, nonanol, or decanol showed similar damage of structure and functional capacity of the retina, optic nerve, optic chiasma, optic tract, anterior corpora quadrigemina, and cerebral optic lobe.

7-109 Flury, F., and O. Klimmer. 1943 (German version 1938). Alcohols, Esters, Aldehydes, Ketones, Ethers, Plasticizers. In: Toxicology and Hygiene of Industrial Solvents. K. B. Lehman and F. Flury, Eds. Translated from German by E. King and H. F. Smith, Jr. The Williams and Wilkins Company, Baltimore, Maryland. pp. 198-325.

C--. General discussion of MeOH use, human and animal toxicity, human poisoning and treatment.

7-016 Funes-Cravioto, F., C. Zapata-Gayon, B. Kolmodin-Hedman, B. Lambert, J. Lindsten, E. Norberg, M. Nordenskjoeld, R. Olin, and A. Swensson. 1977. Chromosome Aberrations and Sister-Chromatid Exchange in Workers in Chemical Laboratories and a Rotoprinting Factory and in Children of Women Laboratory Workers. Lancet 2(8033):322-325.

D-9. Workers were exposed to a variety of organic solvents, such that any possible abberations caused by MeOH are confounded by the other chemicals. Laboratory technicans were exposed to toluene and chloroform in addition to MeOH in each case as well as up to 4 other solvents. Possible exposure to MeOH occurred in 24 of the 73 workers studied. These MeOH exposed workers showed the same significant increase in chromosome aberrations and sister-chromatid exchange as the whole group of 73 workers studied. Authors conclude some environmental factor was causing the increased frequency of chromosome breaks but that the causative agent could not be determined.

7-051 Gadzhiev, G. P., V. G. Deinega, V. V. Sukhanov, I. M. Levshina, N. I. Yarym-Agaeva, and G. A. Petrenko. 1977. Hygienic Evaluation of a New Technology of Methane and Dust Control in Coal Mines. Gig. Sanit. No. 7:24-26 (Russ).

D-4. The physical condition of miners in mines treated with urea-HCHO resin did not differ after several months from that of miners in untreated mines. In treated mines, the air contained 0.02-0.13 mg HCHO/m^3 and 0.14-0.8 mg MeOH/m^3 during cleaning operations. Rats given an intratracheal dose of treated or untreated dust showed more severe bronchial changes if the dust was followed by a 6-mo exposure to 0.5-0.6 mg HCHO/m^3 and 5.0-6.0 mg MeOH/m^3.

7-089 Goss, A. E., and G. H. Vance. 1948. Methanol Vapors from Duplicating Machines may be Health Hazard. Ind. Hyg. Newsletter. 8(9):15.

D--. Study of spirit duplicating machine using solvent ranging from 40-100% MeOH found air concentration during operation to range from 40-635 ppm and depended on % MeOH in solvent and amount of solvent used during operation.

7-149 Gosselin, R. E., H. C. Hodge, R. P. Smith, and M. N. Gleason. 1976 Clinical Toxicology of Commercial Products; Acute Poisoning, 4th ed. The Williams and Wilkins Co., Baltimore, Maryland. pp. 229-233.

D--. Review of MeOH toxicity, symptoms and treatment.

7-150 Gotterer, G. S. 1969. Rat Liver D-β-Hydroxybutyrate Dehydrogenase. III. Inhibition by Topical Anesthetics. Biochem. 8(2):641-645.

D--. High concentration of MeOH, 4,600 mMol of MeOH, required for 50% inhibition of rat liver beta hydroxybutyrate dehydrogenase enzyme.

7-017 Green, L. A. 1977. Methanol: A Selective Cross-Disciplinary Bibliography. National Technical Information Service, Springfield, Virginia. 31 pp.

D--. This bibliography of the literature on MeOH, covering the period 1965 to 1977, contains over 500 references.

7-161 Grob, K. 1965. Gas chromatography of Cigarette Smoke. Part III. Separation of the Overlap Region of Gas and Particulate Phase by Capillary Columns. 3(2):52-56.

D--. Analysis of gas phase portion of cigarette smoke found 180 µg MeOH/cigarette and 45 µg acrolein/cigarette.

7-122 Hale, A. B. 1901. Statement made during discussion following H. Moulton's paper: A Case of Blindness from Drinking Bay Rum, Compared with the Reported Cases Due to Methyl Alcohol and to Essence of Jamaica Ginger, Etc. [pp. 1447-1449]. J. Am. Med. Assoc. 37:1450.

D--. Report of two ingestion cases, review of other cases in literature and discussion of various aspects of MeOH poisoning.

7-113 Hamilton, A. 1925. Industrial Poisons in the United States. MacMillan Company. New York, New York. pp. 418-428

C--. Review of the toxicity of MeOH and of many of the early reported cases of poisoning from industrial exposure.

7-020 Hawes, A. T. 1905. Amblyopia from the Fumes of Wood Alcohol. Boston Med. Sur. J. 153(19):525.

B-4. Case history of painter exposed to MeOH fumes in a closed room. He developed typical smyptoms of MeOH poisoning including loss of vision.

7-078 Hellman, T. M., and F. H. Small. 1974. Characterization of the Odor Properties of 101 Petrochemicals Using Sensory Methods. J. Air Pollut. Control Assoc. 24(10):979-982.

A-3. Determination of odor thresholds using a trained odor panel. Absolute threshold or minimum for 50% of panel was 4.26 ppm; odor recognition threshold for 100% of panel was 53.3 ppm.

2-014 Henderson, Y., and H. Haggard. 1943. In: Noxious Gases and the Principles of Respiration Influencing Their Action, 2nd ed., No. 35, ACS Monograph Series. Reinhold Publishing Corporation, New York, New York. pp. 216-220.

C--. Review of MeOH toxicity information. Contains recommendation that maximum prolonged exposure be below 145-500 mg/m^3.

7-103 Henson, E. V. 1960. The Toxicology of Some Aliphatic Alcohols - Part II. J. Occup. Med. 2(10):497-502.

D--. This brief review of MeOH toxicity includes a discussion of the acidosis and visual effects seen only in primates. Henson stated that the formic acid produced from 100% MeOH conversion is not sufficient to cause the acidosis and proposed that the oxidation of other acids is blocked by the metabolites due to secondary enzyme inhibitions.

7-123 Herbert, J. F. 1902. Blindness from Inhalation of Methyl Alcohol and Charcoal Fumes: Complete Recovery. Am. Med. 3:300.

B-4. Report of case involving a worker who while cleaning and revarnishing a beer vat was exposed to both charcoal stove fumes and MeOH. After 4 d, he because nauseous and dizzy. He slept for 3 d and awoke blind. After treatment, unlike other cases, he recovered his sight.

7-151 Hohne, C., and R. Patsch. 1969. Tolerance Limit of Various Species of Bacteria to Univalent Aliphatic Alcohols. Arch. Hyg. Bakteriol. 153(2):162-167 (Ger).

D--. Bacterial growth of Staphylococcus aureus unaffected by 2% MeOH and Escheriscia coli and Klebsiella pneumoniae by 1% MeOH.

7-022 Holmberg, P. C. 1974. Central-Nervous-System Defects in Children Born to Mothers Exposed to Organic Solvents During Pregnancy. Lancet 2(8135):177-179.

D-9. Study of mothers of children with congenital central-nervous-system defects and their exposure to noxious influences during pregnancy. Significant increase in defects in children of women exposed to organic solvents during 1st trimester of pregnancy. Cases involving MeOH were confounded by exposure to other solvents; also there were no specific exposure measurements.

7-023 Humperdinck, K. 1941. On the Problem of Chronic Intoxication with Methanol Vapors. Arch. Gewerbepathol. Gewerbehyg. 10:569-574 (Ger).

C-6. Study of workers in nitrocellulose plant exposed to MeOH concentrations of 1600-10,900 mg/m^3. Out of 23 workers exposed for 0.5-6 y, one (4 y) developed symptoms of MeOH toxicity--primarily loss of vision, which cleared when exposure was stopped.

1-0172 ILO. 1970. Permissible Levels of Toxic Substances in the Working Environment. Occupational Safety and Health Series 20, International Labour Office, Geneva. pp. 194-198.

C--. Maximum Acceptable Concentrations in Czechosolvakia

	Normal MAC (mg/m^3)	Short, single exposure MAC (mg/m^3)
Acrolein	0.5	1.0
NH_3	40	80
HCHO	2	5
HCN	3	15
MeOH	100	500
H_2S	30	-

7-090 Jansson, B. O. and B. T. Larsson. 1969. Analysis of Organic Compounds in Human Breath by Gas Chromatography-Mass Spectrometry. J. Lab. Clin. Med. 74(6):961-966.

D--. No information is given about the human subjects or their number except that the samples were collected by respiratory mask. The concentrations of organic compounds in ppm determined by GC/MS analysis were methanol, 0.3-3.4; ethanol, 0.05-0.36; acetone, 0.2-0.8; isoprene, 0.09-0.45; and methane, 0-30.

3-133 Jedrychowski, W., K. Prochowska, J. Garlinska, and J. Bruzgielewicz. 1979. Occurrence of Chronic Nonspecific Diseases of the Respiratory Tract in Workers of a Vinyl Resin Plant. Przegl. Lek. 36(9): 679-682 (Pol).

D-7. 456 workers examined, in different departments with different atmospheres including acetaldehyde, MeOH, and NH_3. One group may have been more exposed to NH_3 (0.42-13.39 mg/m^3), along with other compounds and had significantly higher incidence of chronic bronchitis and lower FEV_1 values.

7-024 Jelliffe, S. E. 1905. Multiple Neuritis in Wood Alcohol Poisoning. Med. News 86:387-390.

B-4. Discussion of health hazards from MeOH. Report of two cases of varnishers who developed symptoms of peripheral neuritis, i.e., numbing, prickling, and shooting pain in hands and forearms, pain from pressing nerve trunks, as well as motor weakness. No information on duration of illness or consequences.

5-143 Kamchatnov, V. P., and S. S. Gayazova. 1971. Temperature Asymmetry in Workers Exposed to Formaldehyde Vapor. Hyg. Sanit. 86(1):286-287.

C-8. Exposure to 2.1-7.5 mg MeOH/m^3, 5-78 mg HCHO/m^3, and 47.5-110 mg EtOH/m^3 for 5-20 y caused a pathological skin thermal asymmetry (0.6 to 2.2°C) which existed before a workday began in 48.4% of the workers and increased to 60% by the end of the workday. The authors consider this evidence of adverse CNS effects. Headache, vertigo, and irritability were also reported.

7-025 Kane, L. E., R. Dombroske, and Y. Alarie. 1980. Evaluation of Sensory Irritation from Some Common Industrial Solvents. 41(6): 451-455.

C-8. Mice were exposed to 7,000 to 60,000 ppm of MeOH for 10 min. Calculated RD_{50} value was 41,514 ppm. RD_{50} is level that causes average respiration rate decrease of 50%.

7-156 Kane, R. L., W. Talbert, J. Harlan, G. Sizemore, and S. Cataland. 1968. A Methanol Poisoning Outbreak in Kentucky: A Clinical, Epidemiological Study. Arch. Environ. Health 17(1):119-129.

C--. Incident of MeOH poisoning in 18 people who consumed a drink made from shellac thinner. Discussion of doses and treatments including possible protective effect of ethanol.

5-367 Kettner, H. 1978. Indoor Contamination by Chemical Substances of Daily Use and Their Hygienic Significance. In: Org. Verunreig. Umwelt: Erkennen, Bewerten, Vermidern, K. Aurand, V. Haesselbarth, E. Lahmann, G. Muller, and W. Niemitz, eds. Erich Schmidt Verlag, Berlin, Germany. pp. 448-453 (Ger).

C--. Maximum allowable indoor air in the USSR:

Acrolein	0.1 mg/m^3
NH_3	0.2
HCN	0.002
HCHO	0.01
MeOH	0.5

7-148 Khan, M. A. Q. (1969). Some Biochemical Characteristics of the Microsomal Cyclodiene Epoxidase System and Its Inheritance in the House Fly. J. Econ. Entom. 62(2):388-392.

D--. MeOH stimulated microsomal epoxidation of aldrin by house flies.

7-026 Kimura, E. T., D. M. Ebert, and P. W. Dodge. 1971. Acute Toxicity and Limits of Solvent Residue for Sixteen Organic Solvents. Toxicol. Appl. Pharmacol. 19(4):669-704.

C-12. Toxicity study of newborn rats, young adults, and older adults found LD_{50}'s of 7.4, 13.0, 8.8 mL/kg, respectively. Based on rat response, authors recommend a maximum permissible single oral dose limit of 0.001 mL/kg.

7-027 Kingsley, W. H. and F. G. Hirsch. 1954-1955. Toxicologic Considerations in Direct Process Spirit Duplicating Machines. Compen. Med. 40:7-8.

D-3. Air concentration of MeOH during operation of spirit duplicating machines using solvents of 5-98% MeOH ranged from 15 to 375 ppm in poorly ventilated areas. Employees using these machines reported frequent recurrent and persistent headaches, especially in cooler weather when windows were closed.

7-132 Koelsch, F. 1921. Industrial-Medical Judgement of Wood Spirit or Methyl Alcohol. Zentr. Gewerbehyg. 9:198-203 (Ger).

C--. A review of early reports of methanol intoxication (case histories) and a discussion of methanol's metabolism.

7-028 Koivusalo, M. 1970. Methanol. Int. Encycl. Pharmacol. Ther. 20 (Alc. Deriv., v2):465-505.

D--. Review of the absorption, distribution, elimination and metabolism of MeOH.

7-142 Krotoszynski, B. K., G. M. Bruneau, and H. J. O'Neill. 1979. Measurement of Chemical Inhalation Exposure in Urban Population in the Presence of Endogenous Effluents. J. Anal. Toxicol. 3(6): 255-234.

C--. The expired air from 54 normal, healthy, nonsmoking urban adults (18-60 y old) contained MeOH in 3.6% of the 387 samples. The geometric mean concentration, when found, was 0.549 mg/m^3 (range 0.151-1.99 mg/m^3).

7-029 Leaf, G. and L. J. Zatman. 1952. A Study of Conditions under Which Methanol May Exert a Toxic Hazard in Industry. Br. J. Ind. Med. 9:19-31.

A-7. Exposure of 2 subjects to levels of 655-1430 mg MeOH/m^3. No effects reported other than level of urinary MeOH, which steadily increased during exposure. Subjects (5 males) ingested 29-84 mg MeOH/kg body wt. Constant ratio of 1.3 for concentration of MeOH in urine to concentration in blood from time of ingestion until most excreted 13-16 h later. Study of exposure of workers in ammonia synthesis plant. From these studies it was calculated that exposure to ~ 3,000 ppm would result in gradual accumulation of MeOH in the body.

3-059 Leonardos, G., D. Kendall, and N. Barnard. 1969. Odor Threshold Determinations of 53 Odorant Chemcials. J Air Pollut. Control Assoc. 19(2):91-95.

A-11. Definitive paper. The odor thresholds for various compounds were:

NH_3	46.8 ppm
H_2S	0.00047 ppm
H_2(from Na_2S)	0.0047 ppm
HCHO	1.0 ppm
Acrolein	0.21 ppm
Methanol	100 ppm

7-031 Maddox, W. L., and G. Mamantov. 1977. Analysis of Cigarette Smoke by Fourier Transform Infrared Spectrometry. Anal. Chem. 49(2):331-336.

D--. Analysis method for cigarette smoke. Reports findings of 100-200 μg MeOH/cigarette.

7-030 Machyulite, N. I. 1978. Hygienic Characterization of Working Conditions in the Production of Levomycetin. Gig. Tr. Prof. Zabol. No. 12:8-12 (Russ).

D--. Although concentrations of various chemicals present in the air for different kinds of jobs is given, the health effects observed are not related to the jobs of the workers. The air of the work zone was polluted by styrene, MeOH, dichoroethane, Br_2, i-PrOH, levomycetin, etc., in concentrations often exceeding the MAC's.

7-164 Magrinat, G., J. P. Dolan, R. L. Biddy, L. D. Miller, and B. Korol. 1973. Ethanol and Methanol Metabolites in Alcohol Withdrawal. Nature 244(5413):234-235.

D--. Alcoholics with high blood-ethanol levels had much higher MeOH blood levels compared to low blood-ethanol subjects. The buildup of MeOH may be due to MeOH impurity in the liquor and to endogenous MeOH, whose enzymatic breakdown competes with that of ethanol.

7-093 Majchrowicz, E., and J. H. Mendelson. 1971. Blood Methanol Concentrations During Experimentally Induced Ethanol Intoxication in Alcoholics. J. Pharm. Exp. Ther. 179:293-300.

C--. Alcoholics with high blood-ethanol levels accumulated up to 27 mg MeOH/100 mL in their blood after a 11-day intoxication.

7-112 Martynova, A. P. 1965. Problems of Industrial Hygiene in the Production of the Synthetic Fiber "Lavsan." Gig. Tr. Prof. Zabol. 9(9):13-18 (Russ).

D--. Gases emitted, including MeOH, during specific operations in the production of Lavsan (polyethylene terephthalate) fibers are enumerated, but worker health effects are not evaluated.

7-104 Massachusetts Department of Labor and Industries. 1937. Occupational Health Hazards in Massachusetts Industries IV. Wood Heel Covering. The Commonwealth of Massachusetts Department of Labor and Industries, Division of Occupational Hygiene, Boston, Massachusetts. 7 pp.

D-5. Study of the wood heel covering industry. MeOH was used as a solvent in the cement and in a softener of the celluloid heel covers. Workplace air concentration of MeOH ranged from 110 to 880 ppm. No health effects of inhalation were mentioned.

7-032 May, J. 1966. Odor Thresholds of Solvents for Evaluating Solvent Odors in Air. Staub-Reinhalt Luft. English Translation. 26(9): 385-389.

D-5. Odor thresholds determined for a number of solvents. For MeOH the just perceptible threshold was 7,800 mg/m^3 and the clearly perceptible threshold was 11,700 mg/m^3.

7-073 Mazur, M., S. Dzialek, J. Lembke, and W. Dologicz. 1969. Effect of Methanol and Its Metabolites on the Contraction Amplitude and Coronary Output of the Isolated Rabbit Heart. Agressologie 10(4):317-324 (Fre).

D-7. MeOH caused a rapid and sharp increase in contraction amplitude of an isolated rabbit heart but a decrease in heart rate and cardiac output.

7-094 McAllister, R. G. 1954. Exposure to Methanol from Spirit Duplicating Machines. Am. Ind. Hyg. Assoc. Q. 15(1):26-28.

D--. The solvent for spirit duplicating machines contains 40 to 100% methanol with ethanol and Cellosolve. During use of the machines in small rooms, a probably common practice in schools and business offices, the methanol concentration can attain as high as 635 ppm in the air. No human health effects are mentioned.

7-033 McCord, C. P. 1931. Toxicity of Methyl Alcohol (Methanol) Following Absorption and Inhalation--A Progress Report. Ind. Eng. Chem. 23:931-936.

C-8. Exposure of rats, rabbits, and monkeys to MeOH by inhalation and skin absorption. Inhalation of concentrations of 1,000 to 40,000 ppm caused death, but with marked variation in individual susceptibility. Skin exposure to a concentration of 0.5 cm^3/kg of body wt. applied 4x/d caused illness and death of monkeys. MeOH was detected in organs of animals exposed either by inhalation or skin absorption, but formaldehyde was not present except occasional traces.

7-034 McLean, D. R., H. Jacobs, and B. W. Mielke. 1980. Methanol Poisoning: A Clinical and Pathological Study. Ann. Neurol. 8(2): 161-167.

B-7. Two case histories of alcoholic persons who survived severe MeOH poisoning but developed a Parkinson-like extrapyramidal syndrome. One was blind, the other regained some peripheral vision.

7-075 McMartin, K. E., J. J. Ambre, and T. R. Tephly. 1980. Methanol Poisoning in Human Subjects: Role for Formic Acid Accumulation in the Metabolic Acidosis. Am. J. Med. 68(3):414-418.

B-7. Case histories of 2 men hospilized in a comatose state from MeOH poisoning, only 1 survived. Accumulation of formic acid and its role in acidosis was studied.

7-105 McNally, W. D. 1937. Toxicology. Industrial Medicine, Chicago, Illinois. pp. 613-631.

D--. Review of toxicity of MeOH, of some medical cases involving MeOH poisoning, and of methods of diagnosis and treatment.

7-035 McQueen, E. G. 1978. Toxicology of Methanol/Petrol Blends. In: Alcohol Fuels, Sebel Town House, Sydney, Australia. August 9-11, 1978. R. G. H. Prince, Chairman. J. Chem. Eng. NSW Group. Sidney, Australia. pp. 6/1-6/4.

D-8. Exposure of mice to petrol/15% MeOH mixture for 1 h resulted in 21% mortality compared to 27% for exposure to petrol alone (levels of exposure not reported). Repeated 1-h exposure (2-5x) resulted in 61 and 53% mortality, respectively.

7-160 Menne, F. R. 1938. Acute Methyl Alcohol Poisoning: A Report of 22 Imstances with Postmortem Examinations. Arch. Pathol. 26(1): 77-92.

D--. Case histories of 22 alcoholic men who died from drinking MeOH adulterated alcohol. All were in last stages of poisoning when first treated.

7-037 Moriarity, A. J. 1978. Toxicological Aspects of Alcohol Fuel Utilization. Paper 8-1. In: Proc. Int. Symp. Alcohol Fuel Technol. Methanol, Ethanol, Wolfsburg, Federal Republic of Germany. Nov. 21-23, 1977. CONF-771175, National Technical Information Service, Springfield, Virginia. 5 pp.

C--. Review of toxic properties of MeOH and hazards associated with its possible widespread use as a fuel.

6-124 Newsome, J. R., V. Norman, and V. L. Parotzian. 1965. Vapor Phase Analysis of Cigarette Smoke. Tob. Sci. 9:102-110; or Tobacco 161(4):24-32.

D--. Levels in tobacco smoke (μ g/40 mL puff):

	unfiltered	filtered
MeOH	13	10
HCHO	4.1	3.6
acrollein	8.2	7.9
HCN	32	29
H_2S	3.4	3.1
NH_3	12	13

7-003 New York Department of Labor. 1917. Dangers in the Manufacture and Industrial Uses of Wood Alcohol. Special Bulletin No. 86. State of New York Department of Labor, Division of Industrial Hygiene, Albany, New York. 17 pp.

D-7. Discussion of conditions in various industries producing or using MeOH with suggestions for improving conditions. A number of cases of death, blindness, or other injury are reported from the inhalation of MeOH but no concentrations are given.

7-038 Nikul'tseva, A. A. 1976. Immunological Reaction of Workers in the Synthetic Rubber Industry. Immunopatol. Prof. Porazhenii. 137-147 (Russ).

D--. Workers exposed to 2-9 times the MAC's of HCHO and dimethyldioxane and to 1.7-2.2 times the MAC of isoprene as well as to MeOH and isobutylene vapors showed changes in their immunological reactivity.

7-039 NIOSH, National Institute for Occupational Safety and Health. 1976. Criteria for a Recommended Standard; Occupational Exposure to Methyl Alcohol. HEW Publication No. (NIOSH) 76-148, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 136 pp.

C--. Broad review of animal and human toxicity data and human case exposures. Recommended occupational exposure limit of 200 ppm as time-weighted average exposure for a 10 h workday, 40 h workweek with a 15 min ceiling of 800 ppm.

7-153 Obe, G., and H. Ristow. 1977. Acetaldehyde, but not Ethanol, Induces Sister Chromatid Exchanges in Chinese Hamster Cells In Vitro. Mutat. Res. 56:211-213.

D--. Treatment of cell culture for 7-8 d with 0.1% v/v MeOH daily caused no sister chromatid exchanges.

7-040 Orusev, T., S. Bauer, K. Nikolova, and P. Popovski. 1975. Hygienic Evaluation of Working Conditions in Laboratories of the Organic Chemical Industry. God. Zb. Med. Fak. Skopje. 21:111-116 (Macedon).

D--. Laboratory workers were exposed to 822 ppm benzene, 960 ppm xylene, 202 ppm MeOH, and 764 ppm ethyl ether. Female workers showed difference in psuedocholinesterase activity and increased levels of phenols in urine.

7-041 Pavlenko, S. M. 1972. Certain Common Features of the Effects of Industrial Nonelectrolyte Poisons Entering the Body Simultaneously with Water and Air. Gig. Sanit, 37(1):40-45 (Russ); English Translation available from John Crerar Library, Chicago, Illinois. Order No. 77-13531-06J.

B-7. Rats were exposed by inhalation for 4 h/d for 6 mo to EtOH, MeOH, cyclohexane, and benzene at 1.6, 0.022, 0.066, and 0.018 mg/L, respectively. The same chemicals were simultaneously administered orally at 250, 0.75, 0.05, and 0.25 mg/kg daily, respectively. Increase in the latent period of the conditioned reflexes to positive stimuli and decrease of the strength of the reflexes, especially to weak stimuli, was reported.

5-260 Pavlenko, S. M. and V. A. Guseva. 1973a. Dynamics of the Development of Adaptive Reactions Under the Long-Term Effect of Industrial Poisons Entering an Organism by Different Means. Itogi Nauki Tekh. Farmakol., Khimioter. Sredstva, Toksikol., Probl. Toksikol. 5:110-119 (Russ).

D--. The elaborate set of tests performed on rats exposed to low levels of HCHO, C_2H_5OH, CH_3OH, CC_{14}, or cyclohexanone given by inhalation and/or by mouth does not distinguish the effects caused by each poison; i.e., they each elicit the same responses at nearly the same times.

7-042 Pavlenko, S. M. and V. A. Guseva. 1973b. Development of Adaptive Shifts After Complex Administrations of Nonelectrolyte Poisons. Gig. Sanit. No. 1:15-20 (Russ).

D--. This is a slightly different version of Pavlenko and Guseva (1973a) [5-260].

7-043 Perel, S. S. 1979. Occupational Hygiene in the Manufacture of Some Organosilicon Liquids. Gig. Tr. Prof. Zabol. No. 8:21-25 (Russ).

D--. Workers were exposed to MeOH, benzene, toluene, HCl, organochlorosilanes, hexamethyldisiloxane, and methylphenyldimethoxysilane in the manufacture of organosilicon liquids. Concentrations of the gases were related to jobs but not to the health effects observed.

7-166 Pieper, W. A. and M. J. Skeen. 1973. Changes in Blood Methanol Concentrations in Chimpanzees During Periods of Chronic Ethanol Ingestion. Biochem. Pharmacol. 22:163-173.

D--. Chimpanzees accumulated MeOH in increasing concentration for first 4-5 d of chronic ethanol ingestion. Blood MeOH levels remained at the level through 6-14 wk period until ethanol level declined, then MeOH in blood declined at a rate positively correlated with the rate of elimination of blood ethanol.

7-044 Pigolev, S. A. 1971. Physiological Shifts in Workers from the Isoprene Rubber Industry. Gig. Tr. Prof. Zabol. 15(2):49-50 (Russ).

D--. The isoprene rubber industry workers were exposed to toluene, MeOH, and isopentane at levels within their MAC's but the isoprene concentration was as high as 73 mg/m^3 (18% of the samples exceeded the MAC). Changes in nervous and cardiovascular systems were found.

7-045 Posner, H. S. 1975. Biohazards of Methanol in Proposed New Uses. J. Toxicol. Environ. Health 1(1):153-171.

C--. Discussion of hazards from ingestion, inhalation, or skin absorption of MeOH during its production, handling, and use as a fuel. Reviews of numerous cases of humans poisoned by these types of exposure.

7-144 Potts, A., J. Praglin, I. Farkas, L. Orbison, and D. Chickering. 1955. Studies on the Visual Toxicity of Methanol. Am. J. Ophthalmol. 40(5 Part II):76-82.

D--. Monkeys dosed with 6.0 mg MeOH/kg showed damage to the basal ganglia and retina not seen when other monkeys were given i.v. lethal doses of HCHO or 188 mM Na formate/kg.

7-046 Pryor, G. T., L. R. Bingham, and R. A. Howd. 1978. Behavioral Toxicology in Rats of a Mixture of Solvents Containing Substances Subject to Inhalation Abuse by Humans. Toxicol. Appl. Pharmacol. 45(1):252.

D-7. Exposure of rats to a mixture of methylene chloride, MeOH, heptane, and toluene at 60-226 mg/L for 10 min caused concentration related behavior changes, ataxia, paralysis, and unconsciousness. Cumulative effects were seen from intermittent exposures. MeOH as 10% of mixture was probably not the limiting toxicity.

7-096 Ritchie, J. M. 1970. The Aliphatic Alcohols. In: The Pharmacological Basis of Therapeutics, 4th ed., L. S. Goodman and A. Gilman, Eds. The MacMillan Co., New York, New York. pp. 135-150.

D--. Short review of MeOH toxicity, metabolism, and treatment of poisoning.

7-141 Robinson, J. M. 1918. Blindness from Industrial Use of a 4 Per Cent Admixture of Wood Alcohol. J. Am. Med. Assoc. 70(3):148-149.

C--. Discussion of the dangers of exposure to MeOH. Report on the case of a man who worked dyeing hats for 2-3 h/d. He used a dye containing 4% MeOH which evidently was both inhaled and absorbed through his hands as they were reportedly often stained black. His vision began failing after ~ 3 mo and total blindness followed.

7-133 Roche, L., J. Champeix, L. Echegut, A. Nicolas, and A. Marin. 1957. A Study of the Pathology of Collective Accidents Observed in an Industrial Establishment. Ann. Med. Leg. 37:43-51 (Fre.)

D--. Case studies (6 in detail) of 52 workers making electrical apparatus with a range of medical complaints: narcosis, convulsions, nausea, vomiting, prickling in the extremities, violent headaches, dryness of mouth and pharynx, constriction of the thorax, coma, and syncope. The cause was believed to be vaporization of trichloroethylene and another unknown solvent, probably methanol. Experiments were done on guinea pigs exposed to each of these, alone and together (levels unknown), to confirm the belief. After removal of the solvent vats from the work area, only complaints of slight, benign symptoms were received, the authors attributing them to psychological causes.

7-047 Rodionov, I. S. 1973. Effect of Chemical Factors in the Manufacture of Synthetic Lavsan Fibers on the Health Status of Workers. Gig. Tr. Prof. Zabol. 17(2):1-4 (Russ).

D--. Lavsan fiber workers were exposed to several other compounds (dimethyl terephthalate, ethylene glycol, dinyl, and/or polyethylene terephthalate thermal decomposition products (terephthalic acid and acetaldehyde besides 1.6-25.5 mg MeOH/m^3.

7-048 Rodriguez, R., M. Lorenzana-Jimenez, A. Manjarrez, and H. Gomez-Ruiz. 1978. Behavioral Effects from the Acute and Chronic Inhalation of Thinner in Rats of Various Ages. In: Voluntary Inhalation Ind. Solvents. ADM-79-779, National Institute on Drug Abuse, Alcohol, and Mental Health Administration, U.S. Public Health Service, Department of Health, Education, and Welfare, Rockville, Maryland.

D-6. Rats were exposed to thinner containing 25% MeOH plus toluene, hetone, and other solvent constituents. LD_{50} decreased significantly with increased age, and young rats in general seemed more resistant than adults to effect of solvent, but chronic exposure did retard body development in young rats. Exposure was too confounded to relate any toxicity to MeOH.

7-097 Roe, O. 1955. The Metabolism and Toxicity of Methanol. Pharmacol. Rev. 7(3):399-412.

D--. Review of MeOH toxicity, metabolism, and treatment of poisoning.

7-049 Sayers, R. R., W. P. Yant, H. H. Schrenk, J. Chronyak, S. J. Pearce, F. A. Patty, and J. G. Linn. 1942. Methanol Poisoning. I. Exposure of Dogs to 450-500 P.P.M. Methanol Vapor in Air. Report of Investigations No. 3617, Bureau of Mines, U. S. Department of the Interior. 10 pp.

B-10. Chronic exposure of 4 adult dogs and 4 pups born during exposure period to 450-500 ppm MeOH for 8 h/d for 379 d. No significant variations in blood chemistry or cell counts, in eyes or major organs. Pups were born normal. Blood MeOH levels averaged 7-15 mg/100 ml after 8 h exposure but dropped to < 5 mg/100 mL 16 h later.

7-116 Sayers, R. R., W. P. Yant, H. H. Schrenk, J. Chornyak, S. J. Pearce, F. A. Patty, and J. G. Linn. 1944. Methanol Poisoning II. Exposure of Dogs for Brief Periods Eight Times Daily to High Concentrations of Methanol Vapor in Air. J. Ind. Hyg. 26(8):255-259.

C-7. Exposure of 2 dogs to ~ 10,000 ppm for ~ 3 min, 8 x/d for 100 d. No effect on weight, blood, or eyes. Blood MeOH levels increased during 8 h exposure, decreased frequently to 0 before next day's exposure.

7-050 Scherberger, R. F., G. P. Happ, F. A. Miller, and D. W. Fassett. 1958. A Dynamic Apparatus for Preparing Air-Vapor Mixtures of Known Concentrations. Am. Ind. Hyg. Assoc. J. 19:494-498.

D-10. Determination of odor thresholds using an air blender, which is described in detail. Odor threshold for MeOH was reported as 1,500 ppm, which is very high compared to other reported odor thresholds.

7-051 Schneck, S. A. 1979. Methyl Alcohol. In: Handbook of Clinical Neurology, Vol. 36, Intoxications of the Nervous System, Part 1. P. J. Vinken, and C. W. Bruyn, Eds. Elsevier/North-Holland, Inc., New York, New York. pp. 351-360.

D--. A good review of methanol poisoning and the presumed role of HCHO.

7-052 Scott, J. B. 1978. Exposure of Mice to Methylene Chloride and Methanol Alone and in Combination. UR-3490-1413. National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia.

B-9. Mouse LC_{50} for MeOH determined as 41,000 ppm. Mice were exposed to 1,000 ppm MeOH 6 h/d, 5 d/wk for 3 wk. No deaths, abnormal behavior, wt. changes, or eye damage; some lowering of liver triglycerides. Eye damage did occur during the 6 h exposure at LC_{50} level.

7-135 Scott, E., M. K. Helz, and C. P. McCord. 1933. The Histopathology of Methyl Alcohol Poisoning. Am. J. Clin. Path. 3:311-319.

C--. Study involving exposure of 31 rhesus monkeys, 58 rabbits, and 176 albino rats to unspecified levels of MeOH by either inhalation, skin absorption, or ingestion. Threshold of danger reported to be < 1,000 ppm for inhalation and 0.5 cm^3 MeOH/kg of body wt, 4 x/d by skin absorption. In-depth discussions of pathological findings, these included changes in liver, spleen, kidneys, heart, lungs, vascular and nervous systems including optic nerve degeneration.

7-166 Sedivec, V., M. Mraz, and J. Flek. 1981. Biological Monitoring of Persons Exposed to Methanol Vapors. Int. Arch. Occup. Environ. Health 48(3):257-271.

A-10. Study of relationship between level of MeOH exposure and MeOH urine levels in humans. A correlation was found between level of exposure and level of MeOH excreted in urine when measured in mg/L or mmol/L.

7-158 Self, R., J. C. Casey, and T. Swain. 1963. The Low-Boiling Volatiles of Cooked Foods. Chem. Ind. No. 21:863-864.

D--. MeOH was detected in a number of cooked foods after boiling for 30 min. Levels were not quantified; but brussel sprouts, cauliflower, onion, parsnip, potato, and swede were described as having "large" or "very large" levels of MeOH.

7-054 Sova, B. 1979. Harmful Chemicals in the Air of the Working Environment from the Standpoint of New Regulations. Kozarstvi. 29(6):153-155 (Czech).

C--. Maximum permissible concentration of MeOH in workplace air is 100 mg/m^3.

7-125 Stricker, L. 1908. The Toxic Amblyopias. Lancet-Clinic 99(18): 481-499.

C--. Discussion of human cases involving blindness due to exposure to MeOH of unknown concentration. Two cases of inhalation discussed, one a review of a previously published case in Wood and Buller (1904) and a new one concerning a man overcome while shellacking the interior of a hot beer vat. This short exposure of < 0.5 d resulted in total blindness.

7-077 Takeda, I. 1972. Metabolism of Alcohol, with Reference to that of Ethanol and Methanol in the Rabbit. Nichidai Igaku Zasshi. 1(6):518-526 (Japan).

C--. MeOH administered orally to rabbits was excreted in 40 h compared to 7 h for EtOH. The MeOH was not appreciably metabolized, which may account for its lower toxicity in rabbits compared to other mammals.

7-055 Tephly, T. R. 1977. Factors in Responses to the Environment. Organismal Response to the Environment. Introduction. Fed. Proc., Fed. Am. Soc. Exp. Biol. 36(5):1627-1628

C--. Review of metabolism and toxicity of MeOH in humans and monkeys. Comparison is made with rats, which are much less sensitive to MeOH, and differences are discussed.

7-056 Tephly, T. R., W. D. Watkins, and J. I. Goodman. 1974. The Biochemical Toxicology of Methanol. In: Essays in Toxicology, Vol. 5, W. J. Hays, Jr., Ed. Academic Press, New York, New York. pp. 149-177.

D--. Review of the metabolism of MeOH, HCHO, and formic acid. It is proposed that HCHO is likely the cause of MeOH toxicity but that its presence is rarely verified in tissues because of its high reactivity.

7-057 Tephly, T. R., A. B. Maker, K. E. McMartin, S. S. Hayreh, and G. Martin-Amat. 1979. Methanol. Its Metabolism and Toxicity. Biochem. Pharmacol. Ethanol. Vol. 1, E. Majchrowicz and E. P. Noble, Eds. Plenum Press, New York, New York pp. 145-164.

D--. Review of metabolism of MeOH, HCHO and formate, review of information on metabolic acidosis and ocular toxicity and discussion of MeOH poisoning treatment.

7-059 Thomas, M., A. L. A. Boura, and R. Vijayakumar. 1980. Prostaglandin Release by Aliphatic Alcohols from the Rat Isolated Lung. Clin. Exp. Pharmacol. Physiol. 7(4):373-381.

D-8. An evaluation of the ability of MeOH to release prostaglandins from rat isolated perfused lung. Increasing concentrations, up to 0.02 mM MeOH, caused increased prostaglandin release, higher concentrations caused a decrease.

7-060 Timourian, H. and F. Milanovich. 1979. Methanol as a Transportation Fuel: Assessment of Environmental and Health Research. UCRL-52697, National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia. 97 pp.

D--. Review of health and environmental impacts of the use of MeOH as a fuel. In depth analysis of available knowledge for gaps that need filling in order for the full impact of MeOH fuel use to be assessed. Areas needing further research are pointed out and recommended research outlined.

5-402 Tremer, H. M., H. L. Falk, and P. Kotin. 1959. Effect of Air Pollutants on Ciliated Mucous-Secreting Epithelium. J. Nat. Cancer Inst. 23(5):979-997.

D-8. Methods developments for measuring effect of various atmospheric contaminants on respiratory epithelium in vitro. Sections of the ciliated epithelium of the esophageal tract of the leopard frog were exposed to 1.1-3.3 mg HCHO or 0.4-1.4 mg MeOH in aerosols at the rate of 27 mL/s for 2 s. Mucous flow was inhibited by HCHO and accelerated by MeOH.

7-061 Tyson, H. H. O. 1912. Amblyopia from Inhalation of Methyl Alcohol. Arch Ophthalmol. 16:459-471.

B-5. Case studies of 3 individuals exposed by inhalation and possibly skin absorption to MeOH while working. Typical symptoms of MeOH toxicity including damage to vision. Two cases were chronic exposure where the severity of symptoms decreased when exposure was reduced by proper ventilation. One case was acute exposure and permanent damage to vision occurred from the 2 d exposure to MeOH. Levels of MeOH involved in exposures were not reported.

7-117 Tyson, H. H. and M. J. Schoenberg. 1914. Experimental Researches in Methyl Alcohol Inhalation. J. Am. Med. Assoc. 63(11):915-922.

C-8. Early exposure study using rabbits, dogs, and monkeys but with poor information on quantity of MeOH used in exposures. Effects included death at higher concentrations, acidosis, hemorrhages and congestion of internal organs, eye damage, and blindness.

7-062 Ubaydullayev, R. 1968. A Study of Hygienic Properties of Methanol as an Atmospheric Air Pollutant. In: U.S.S.R. Literature on Air Pollution and Related Occupational Diseases; Volume 17; A Survey, B.S. Levine (translator) PB 180522, National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia. pp. 39-45.

A-8, Human, B-8, Animal Tests. Odor threshold determined as 4.5 mg/m^3, concentration causing change in human eye sensitivity, 3.5-4.1 mg/m^3, in electrical brain reflexes, 15 mg/m^3. Rats exposed continuously to 5.3 mg/m^3 for 90 d had changes in chonaxy indexes, and in blood and urine biochemistry. No effect on rats exposed to 0.5 mg/m^3.

3-094 U.S.S.R. State Committee of the Council of Ministers for Construction. 1972. Sanitary Norms for Industrial Enterprise Design. Izdatel'stvo Literatury po Stroitel'stvu [Publishing House of Literature on Construction]. Moscow. 96 pp.

C--. In the USSR, the MAC for MeOH in workplaces was 5 mg/m^3, and 1 mg/m^3 as the one-time limit and 0.5 mg/m^3 as the average limit in populated places.

5-413 Van Gemert, L. J. and A. H. Nettenbreijer. 1977. Compilation of Odour Threshold Values in Air and Water. National Institute for Water Supply. Leidschendam, The Netherlands, and Central Institute for Nutrition and Food Research, TNO, Zeist, The Netherlands.

A--. Compilation of odor threshold values reported by different researchers, for many compounds, including:

NH_3	0.03-37 mg/m^3
HCN	< 1.1-6
H_2S	0.001-2
HCHO	0.033-2.2
MeOH	4.3-19,300
Acrolein	0.05-4.

7-063 Varela Rodelo, F. 1978. Biochemistry of Methanol Intoxication. Rev. Inst. Nac. Med. Leg. Colomb. 3(1):79-91 (Spa).

D--. Review of the toxicity and metabolism of MeOH.

5-111 Vilisov, B. A., N. S. Irger, L. M. Kremko, Z. N. Pavlyutina, I. G. Tseluiko, Y. S. Danishevich, and S. S. Khudnitskii. 1980. Hygienic Evaluation of Some Synthetic Resins and Their Effect on the Health of Molding Department Workers. Zdravookhr. Beloruss. No. 1:31-34 (Russ).

D-7. Foundry core makers using phenol-formaldehyde copolymer, urea-formaldehyde, and furan resins suffered a higher rate of disorders of the skin, liver, kidney, and respiratory organs compared to workers involved in machine building. Metal casting workers using these resins were ill about half as often and half as long as the core makers. Amounts of substances released in g/ton during mixing and hardening of the resins (and during heating of the molds up to 800°C) were as follows: HCHO, 0.4-34.6 (not detected to 10.4); phenol, N. D. (not detected) to 1.7 (N.D.-8.5); MeOH, 1.6-124.9 (N.D.-4.2); furfurol, N.D.-2.9 (N.D.-1.6); furyl alcohol, N.D.-142.7 (N.D.); NH_3, 0.3-16.7 (1.2-1875.5); CO, N.D.-61.5 (12.7-4014.7); and HCN, N.D.-0.6 (N.D.-376.3). Thus, the more frequently ill core makers were exposed to more HCHO, MeOH, and furyl alcohol than the casters; and the casters were exposed to more phenol, NH_3, CO, and HCN than the core makers.

7-100 Von Oettingen, W. F. 1943. The Aliphatic Alcohols--Their Toxicity and Potential Dangers in Relation to their Chemical Constitution and Their Fate in Metabolism. Public Health Service Bull. 281. 253 pp.

D--. In-depth review of the toxicity of MeOH to both animals and humans and of pathology resulting from various types of exposure.

7-101 Von Oettingen, W. F. 1958. Poisoning; A Guide to Clinical Diagnosis and Treatment. 2nd ed., W. B. Saunders Co., Philadelphia, Pennsylvania. pp. 425-427.

D--. In-depth description of MeOH poisoning symptoms and suggested treatment.

7-064 Winek, C. L., W. D. Collom, and E. R. Davis. 1973. Accidental Solvent Fatality. Clin. Toxicol. 6(1):23-27.

D-6. Case history of man overcome while removing paint from wall in church. He was using a product containing benzene, MeOH, and acetone. He died after < 3 h exposure. Autopsy finding were 6-27% benzene, 1-6% MeOH, and 3-8% acetone in the tissues sampled.

7-119 Witte, R. 1934. Methylalkohol. In: Flury, F., and W. Wirth. Toxicology of Solvents. Arch. Gewerbepath Gewerbehyg. 5:58-63 (Ger).

C--. A review largely devoted to describing the results of Loewy and Von der Heide (1914) [7-114].

7-065 Wood, C. A. 1912. Death and Blindness from Methyl or Wood-Alcohol Poisoning with Means of Prevention. J. Am. Med. Assoc. 59(22):1962-1966.

C-5. Discussion of the dangers of MeOH, illness and death caused by its improper use. Legal remedies and means of prevention are discussed. Three more cases of workers poisoned by MeOH while shellacking the interior of beer vats are presented. One appeared to recover without serious effects, one was blinded, and the other one died.

7-066 Wood, C. A. and F. Buller. 1904. Poisoning by Wood Alcohol. Cases of Death and Blindness from Columbian Spirits and other Methylated Preparations. J. Am. Med. Assoc. 43:972-977,1058-1062, 1117-1123, 1213-1221, and 1289-1296.

C--. Summary of health hazards of MeOH. Contains a number of reports of individual cases, both ingestion and inhalation. Most report typical MeOH poisoning symptoms, especially blindness.

7-120 Yant, W. P. and H. H. Schrenk. 1937. Distribution of Methanol in Dogs after Inhalation and Administration by Stomach Tube and Subcutaneously. J. Ind. Hyg. 19(7):337-345.

C-7. Inhalation by dogs of 4000 ppm MeOH for 12 h resulted in blood MeOH levels of 100 mg/100 g; a 5 d exposure resulted in levels of 317-570 mg/100 g, that dropped to 0 after 120 h. Similar levels resulted from ingestion and subcutaneous exposure to 2.5-5.0 g MeOH/kg body wt. Inhalation of 15,000 ppm for 24 h resulted in blood MeOH levels of 1390-1470 mg/100 g, falling to 335 mg/100 g 48 h later. The distribution of MeOH in tissues and fluids closely followed the amount of water in various tissues and fluids.

7-138 Yant, W. P., H. H. Schrenk, and R. R. Sayers. 1931. Methanol Antifreeze and Methanol Poisoning. Ind. Eng. Chem. 23(5):551-555.

D-4. General information on study of health effects of inhalation or skin absorption of MeOH antifreeze. Inhalation and dermal studies on animal described with no results reported. Occupational study of worker in MeOH production plants and truck drivers who were users of the antifreeze. No harmful health effects noted in exposed persons but no details of study reported.

7-067 Zhigunov, N. F. 1976. Effect of Industrial Factors on Certain Indexes of Cellu ar Immunity in Workers Manufacturing Synthetic Fibers. Aktual. Vopr. Okhr. Tr. Khim. Prom-sti. pp. 57-59 (Russ).

D--. Workers spinning Lavsan fibers were exposed to terephthalic acid, acetaldehyde, dimethyl terephthalate, ethylene glycol, MeOH, CO, and crotonaldehyde below their MAC's. The chemical department workers were exposed to terephthalate esters and MeOH above their MAC's and to ethylene glycol and dinyl below the MAC's. The changes in phagocytosis in the workers of both departments of Lavsan production were usually in the form of inhibition, which was more distinct and more stable after a year of work.

7-068 Ziegler, S. L. 1921. The Ocular Menace of Wood Alcohol Poisoning. J. Am. Med. Assoc. 77(15):1160-1166.

B-7. Discussion of the hazards of MeOH and the reporting of several human cases, two involving toxicity from inhalation of unknown concentrations. One was an acute 3 d exposure, the other a chronic exposure of 1 h/d for some period of time. Both subject showed typical MeOH toxicity symptoms, especially eye damage.